LAYOUTS AND OPERATING CRITERIA FOR AUTOMATION OF DAIRY PLANTS PROCESSING CHEDDAR CHEESE

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PREFACE

This is the last of a series of six reports submitted by P. H. Tracy under a research contract with the Transportation and Facilities Research Division, Agricultural Research Service, U.S. Department of Agriculture. These reports were prepared for Department publication by T. F. Webb, investigations leader, Handling and Facilities Research Branch, Transportation and Facilities Research Division.

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LAYOUTS AND OPERATING CRITERIA FOR AUTOMATION OF DAIRY PLANTS PROCESSING CHEDDAR CHEESE

By P. H. Tracy [1]

SUMMARY

Automated and highly mechanized operating methods and an improved layout can reduce costs for dairy plants manufacturing cheddar cheese.

Labor costs in a plant handling 800,000 pounds of milk weekly would be about $136,500 less on an annual basis in an automated plant with an improved layout than in a nonautomated plant with a typical layout. Production for the automated plant is estimated to be 88 pounds of cheddar cheese per man-hour and for a nonautomated plant, 45 pounds. Costs of the additional equipment required to make these savings possible are estimated at $262,000. If 20 percent of this extra cost ($52,400) is allowed annually for costs of ownership and operation of the equipment, (depreciation, maintenance, insurance, taxes, and interest) the net savings due to automation would be $84,100 annually.

The cleaning operation has the greatest reduction in cost in the automated plant; however, all operations can be performed more economically in the automated than in the nonautomated plant.

Layouts were developed for a plant handling 800,000 pounds of milk weekly. The layouts show arrangement of equipment and work and storage areas for the most efficient flow of products, containers, and supplies throughout the plant. Provision is made for future expansion to double the original production.

BACKGROUND OF THE STUDY

The cheddar cheese industry had its beginning in the farm homes of the early American pioneer families. The first commercial plant was built in Rome, N.Y., in 1851. Wisconsin, however, soon became the leading State in production of cheddar cheese and by the mid-1960's produced over 40 percent of the Nation's output.

American cheese production, being to some extent an outlet for surplus milk, varies in quantity from year to year, but the general trend in production has been upward. The total production in 1964 was 1.2 billion pounds compared with 0.9 billion pounds in 1954. In 1930, 5 percent of the total milk production was used in making cheese. Thirty years later, this percentage had increased to 10.9. During this time, the American people had definitely increased their use of this food. In 1930 the per capita consumption of American cheese was 3.2 pounds, and by 1960, this figure had increased to 5.4 pounds. The growing popularity of cheese is due to its relatively low cost, as well as the improved quality, packaging techniques, and marketing methods.

A definite part of the evolution of the cheese industry has been the growth in size of plants. This increase in size was made possible by im-

[1] Dr. P. H. Tracy, formerly professor of dairy technology, Department of Food Science, University of Illinois, conducted the study and prepared the report under a research contract with the U.S. Department of Agriculture.

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proved methods of producing and gathering milk from farms and mechanization and automation of manufacturing. Traditionally, much hand labor has been required in making cheese, since for many years cheesemaking has involved methods based more on art than on science. Through research, many of the procedures have been improved and reduced to standardized machine practices. Some tedious and extensive hand labor is still required in changing milk into cheddar cheese, but mechanized and automated methods are being developed at a rapid pace.

Modern cheddar cheesemaking involves careful bacteriological care of cultures; methods for controlling bacteriophage, a virus infection of starter cultures; automatic control of pasteurization and cooling methods; use of large refrigerated storage vats to hold over raw milk supplies to even out daily plant operation; large cheesemaking vats with mechanical agitators; mechanical methods for milling and salting the curd and for handling hoops; use of pallets and lift trucks; CIP (cleaned-in-place) cleaning of equipment; automatic control of steam production and refrigeration; and careful and detailed scheduling of workers in the cheese plant.

The heart of the process—cheddaring—remains a hand operation. Mechanized methods, however, are being developed. Cheddaring involves piling the curd down each side of the vat and cutting it into pieces about 5 by 4 by 26 inches, which are turned by hand to permit drainage of whey and to start surface sealing. After three or four turns, these long strips are cut into two crosswise chunks; and the front chunks are turned by hand and laid directly on top of the rear chunks. These pieces are then turned every 5 minutes and piled three or four high, the top pieces being transferred to the bottom with each turn. As the result of bacterial and rennet action, the curd begins to knit together and to become plasticized. This continues until the curd is milled and salted. The knitting and plasticizing transform the curd from a mass of separate ¼-inch chunks to a homogeneous mass that flows and flattens, becomes somewhat rubbery, and has a final texture very much like that of breast of chicken. It has a definite grain at this final stage before milling, and continuous strips as long as 30 inches can be pulled from the mass.

If this turning procedure, which results in the flowing and flattening characteristic of the cheese, is omitted some savings in labor result, but the cheese has excessive mechanical holes and whey pockets. Such cheese is more likely to be curdy like open-textured Colby cheese.

Mechanization of this part of cheddar cheesemaking, therefore, has not been used in this study, since it is not yet in general use in the industry. Several research workers in the United States and Australia at the time of this study have almost succeeded in duplicating with mechanical methods the true cheddar type, which is desirable for long-held cheese of the sharp-cured variety.

The purpose of this study is to supply the dairy industry with information and guidelines that will be helpful in (a) increasing the productivity of labor in dairy plants, (b) improving quality by establishing more uniform and better controlled methods of operation, (c) improving working conditions by minimizing the number of jobs requiring difficult and tedious labor, and (d) reducing the amount of plant loss and shrinkage through more positive control of operating procedures. Such information should be helpful in the remodeling of old plants as well as in building new ones.

New equipment that has been proved commercially feasible for mechanizing the processes involved in the manufacture of cheddar cheese is described in the report, and the application of electronic control devices for automatic operation is explained.

A flow diagram and a layout of the site showing the desirable position of a cheddar cheese plant on an assumed location are provided for a plant handling 800,000 pounds of milk weekly.

The equipment needed to operate the plant is shown on the plant layout. The labor needed for performing the various operations involved is listed, and the labor cost for such an operation is compared with the estimated labor cost of a nonautomated and less mechanized operation of the same size.

Somewhat detailed explanations are given of the methods involved in operating a cheddar cheese factory, including disposition of the whey.

ASSUMPTIONS REGARDING PLANT OPERATION

To illustrate principles of plant layout and methods of operation for an automated cheddar cheese plant, it was necessary to make certain assumptions. They were as follows:

1. The plant will handle 800,000 pounds of milk testing 3.6-percent fat and 8.8-percent milk solids-not-fat weekly. A 25-percent variation, plus or minus, in seasonal production will be allowed.
2. The milk will be purchased from local producers, and deliveries will be made daily in tank trucks.
3. The plant will operate 6 days per week. Workers will put in 40 hours per week.
4. The cheese will be made from pasteurized milk. Proper methods will be provided for the control and prevention of bacteriophage growth in the cultures and cheese vats.
5. The cheese will be made into the following styles and sizes:

Style	Percentage of total production	Size of cheese	Average weight of cheese	Height of hoop
		Inches	*Pounds*	*Inches*
Twin	30	14½ × 5¼	30	9½
Daisy	25	13½ × 3¾	20	6½
Cheddar	25	14½ × 11¼	75	15½
10-lb. print	20	7 × 11 × 3½	10	4½ (20-lb. hoop)

6. Provisions will be made for storing the cheese 30 days before shipment.
7. Equipment will be provided to condense the whey to 40-percent total solids for shipment to a dried whey plant.
8. Mechanical losses will not be considered.
9. The whey cream will be sold in bulk to a butter-processing plant.

An inventory schedule was developed from these assumptions. Since receipts will be 800,000 pounds per week, plus or minus 25 percent for seasonal variation, and since a 6-day cheesemaking week is desired, the plant will handle 180,000 pounds of milk for maximum production and 160,000 pounds for minimum (table 1).

The plant can operate with one day's receipts, or it can hold over all milk, or it can process part of it. Capacity of the holding tank is provided for the maximum daily operation of 180,000 pounds (nine vats). With cold-wall storage tanks, any amount of milk that cannot be put into the vats on schedule can be held to the next day.

TABLE 1.—*Utilization of milk in a cheddar cheese plant handling 800,000 pounds weekly, with 25 percent allowance for seasonal increase in production*

Day	Quantity of milk— Received	Stored	Processed	Total cheese made [1]
	Pounds	*Pounds*	*Pounds*	*Pounds*
Monday	142,857	105,715	180,000 (9 vats)	17,366
Tuesday	142,857	68,572	180,000 (9 vats)	17,366
Wednesday	142,857	51,429	160,000 (8 vats)	15,437
Thursday	142,857	34,286	160,000 (8 vats)	15,437
Friday	142,857	17,143	160,000 (8 vats)	15,437
Saturday	142,857	None	160,000 (8 vats)	15,437
Sunday	142,858	142,858	None	None

[1] Cheese yield based on formula: 2.68 × pounds of fat in given quantity of milk = pounds of cheese produced.

As a practical measure, the daily production should be scheduled so that only one style is packaged from a vat. A breakdown on this basis would be:

3 vats, 30-pound twins per day
2 vats, 20-pound daisies per day
2 vats, 75-pound cheddars per day
2 vats, 10-pound prints per day

The schedule for one week is shown in table 2. The production of daisies and cheddars will need to be alternated every other Saturday to obtain the exact percentage specified for these two items.

TABLE 2.—*Number of vats of each style of cheese made on specified day of week*

Day	Number of vats: Twins	Daisies	Cheddars	Prints	Total
	Number	*Number*	*Number*	*Number*	*Number*
Monday	3	2	2	2	9
Tuesday	3	2	2	2	9
Wednesday	3	2	2	1	8
Thursday	2	2	2	2	8
Friday	2	2	2	2	8
Saturday	2	2	3	1	8
Total	15	12	13	10	50

SUGGESTED LAYOUT OF THE PLANT

The suggested layout of the plant is shown in figure 1. The layout is arranged for efficient flow of products and containers, space utilization, equipment arrangement, labor utilization, and possible future expansion.

Two buildings are recommended. The building for the cheesemaking operations is rectangular. Its dimensions are 327 feet 6 inches long, and 184 feet 8 inches wide, covering an area of 60,479 square feet. Part of this area, which is adjacent to the milk-processing room, is not under cover. The milk storage tanks are on concrete slabs and extend through the wall of the pasteurizing room.

Adjacent to this building is a second one containing 5,651 square feet of floorspace. The whey-processing facilities, the shop, the boiler room, and the refrigeration room are in this second building.

The two buildings are connected by an underground passageway, or tunnel, through which power, steam, water, whey, and refrigeration lines pass. This arrangement separates the whey-processing from the cheesemaking operations. Since the whey evaporator uses large amounts of steam, the boiler should be located close by.

Components of the Facility

The major components of the plant are as follows:

1. Tanker-receiving shelter
2. Milk weighing, storing, clarifying, and pasteurizing area
3. Cheesemaking area
4. Starter room
5. Hoop washing and storing and print-wrapping room
6. Cheese drying and paraffining room
7. Cheese storage room
8. Dry storage room
9. Loading dock
10. Refrigeration, shop, and boiler room
11. Offices
12. Plant locker and restrooms
13. Laboratory
14. Lunchroom
15. Whey-handling area

The components are arranged to provide for short, direct flow of products and containers and to minimize travel and handling. Requirements for space for each component are based on the size of the equipment and the working space needed for efficient operation. Size of storage rooms is determined by the number and size of items to be stored, the method of stacking, and the length of the storage period. Allowances for aisles are based on the type and amount of traffic handled. The components of the plant are designed and arranged so that expansion will not present a major construction problem.

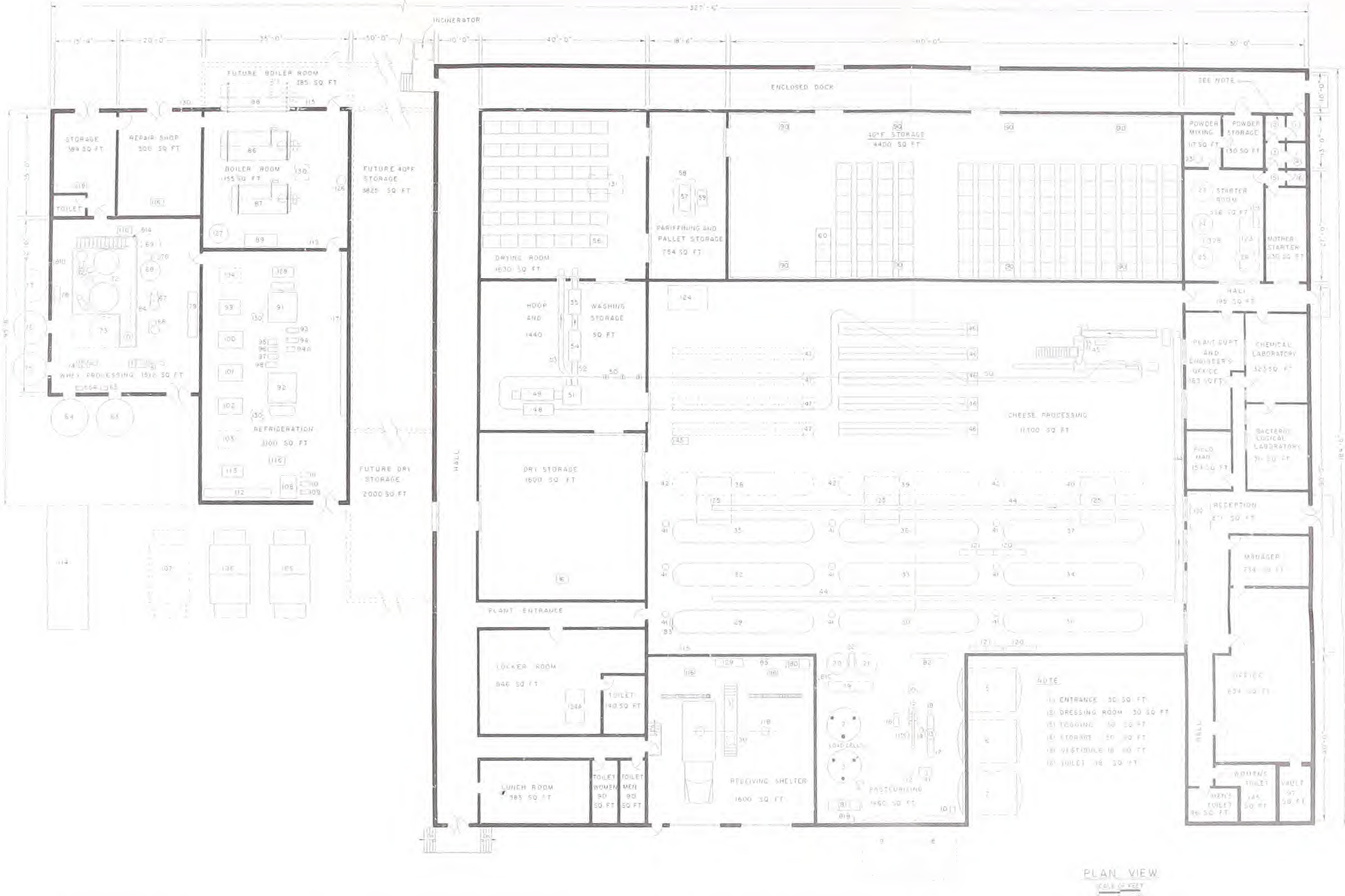
Figure 1 shows the arrangement of each item of equipment in each component. Each item is numbered and is referred to by this number (in parentheses) in the discussion of the various components.

TANKER-RECEIVING SHELTER

As the amount of raw milk the plant will receive from local producers will vary with the season, ranging from 85,714 to 142,857 pounds per day, the number of 3,000-gallon tank trucks delivering to the plant daily will vary from four to seven. After the milk is unloaded with the raw milk receiving pump (1), the truck tanks are washed. Other jobs performed in the shelter are inspecting the raw milk and taking samples for analysis.

The tanker-receiving shelter provides space for two trucks at a time, so that one can be cleaned while the other is being unloaded. The shelter is 40 feet wide and 40 feet long. It has a 3-foot island 42 inches above ground level running lengthwise down the shelter dividing it into two truck positions. This platform is even with the walkway on the tank trucks to make it easy for workers to get to the tank manhole.

The floor of the tanker-receiving shelter should be constructed of brick tile pitched toward the rear at not less than one-half inch per foot to permit complete and rapid draining of milk from the tank trucks. A floor drain is located toward the rear of the receiving room to carry away the wash and rinse water used in cleaning the pump compartments on the tank truck.



- 1 RAW MILK RECEIVING PUMP, 150 G.P.M.
- 2, 3 VERTICAL WEIGH TANKS, 3,500 GAL, ON LOAD CELLS
- 4 RAW MILK TRANSFER PUMP, 100 G.P.M.
- 5, 6, 7 HORIZONTAL STORAGE TANKS, 8,000 GAL.
- 8, 9 FUTURE HORIZONTAL STORAGE TANKS, 8,000 GAL.
- 10 CENTRIFUGAL PUMP TO FEED CLARIFIER, 20,000 LB. PER HR.
- 11 COLD MILK CLARIFIER, 20,000 LB. PER HR.
- 12 FUTURE COLD MILK CLARIFIER, 14,275 LB. PER HR.
- 13 BALANCE TANK, 30 GAL.
- 14 CENTRIFUGAL BOOSTER PUMP, 20,000 LB. PER HR.
- 15 PLATE HEAT EXCHANGER, 20,000 LB. PER HR. EXPANDABLE TO 31,250
- 16 MEASURED FLOW TIMING PUMP, 20,000 LB. PER HR.
- 17 HOLDER TUBE, 20,000 LB. PER HR.—16 SECONDS
- 18 FLOW DIVERSION VALVE
- 19 HEATING AND CIRCULATING UNIT FOR HTST SYSTEM
- 20 VACUUM PRESSURE STARTER STORAGE TANK, 300 GAL.
- 21 FUTURE VACUUM PRESSURE STARTER STORAGE TANK, 300 GAL.
- 22 MEASURE FLOW POSITIVE PUMP
- 23 POWDER MIXING FUNNEL AND PUMP ASSEMBLY
- 24, 25 VACUUM PRESSURE CULTURE VATS, 100 GAL.
- 26, 27 FUTURE CULTURE VATS, 100 GAL.
- 28 CENTRIFUGAL CULTURE TRANSFER PUMP, 10,000 LB. PER HR.
- 29–34 CHEESE VATS, 20,000 LB.
- 35–40 FUTURE CHEESE VATS, 20,000 LB.
- 41 WHEY DRAINING TANKS
- 42 FUTURE WHEY DRAINING TANKS
- 43 POSITIVE DISPLACEMENT WHEY PUMP, 50,000 LB. PER HR.
- 44 SLAB CURD CONVEYOR
- 45 CURD MILLING, SALTING AND WEIGHING MACHINE, 5,000 LB. PER HR.
- 46 FIVE CHEESE PRESSES, 16-FOOT, DOUBLE ROW
- 47 FOUR FUTURE CHEESE PRESSES, 16-FOOT, DOUBLE ROW
- 48 CONVEYOR CAN WASHER
- 49 CHEESE HOOP WASHER
- 50 OVERHEAD HOOP CONVEYOR
- 51 DEHOOPING TABLE
- 52 PRINT CHEESE CONVEYOR
- 53 TOONG CHEESE CONVEYOR
- 54 CHEESE PRINT WRAPPING AND SEALING MACHINE
- 55 BOXING MACHINE TABLE
- 56 CHEESE DRYING SHELVES
- 57 PARAFFIN TANK WITH ELECTRIC LIFT
- 58 EXHAUST HOOD FOR PARAFFIN TANK
- 59 TABLE AND SCALES
- 60 PALLETS, 45 BY 45 IN.
- 61 UNCONCENTRATED WHEY PLATE HEAT EXCHANGER
- 62 VAPOR LINE WHEY PREHEATER, 20,000 LB. PER HR.
- 63 VERTICAL (SILO) WHEY STORAGE TANK, 3,000 GAL.
- 64 VERTICAL (SILO) WHEY STORAGE TANK, 12,000 GAL.
- 65 CENTRIFUGAL WHEY FEED PUMP, 20,000 LB. PER HR.
- 65A CENTRIFUGAL WHEY FEED PUMP, 20,000 LB. PER HR.
- 66 WHEY CLARIFIER, 20,000 LB. PER HR.
- 67 WHEY SEPARATOR, 20,000 LB. PER HR.
- 68 WHEY CREAM COOLING AND STORAGE TANKS, 300 GAL.
- 69 FUTURE WHEY CREAM COOLING AND STORAGE TANK, 300 GAL.
- 70 WHEY CREAM PUMP, 25 G.P.M.
- 71 WHEY TUBULAR PREHEATER, 20,000 LB. PER HR.
- 72 DOUBLE EFFECT RECOMPRESSION WHEY EVAPORATOR, 20,000 LB. PER HR.
- 73 FUTURE FIRST EFFECT TO EXPAND WHEY EVAPORATOR TO 31,000 LB. PER HR.
- 74 CONCENTRATED WHEY PLATE COOLER, 7,000 LB. PER HR.
- 75, 76 VERTICAL (SILO) CONDENSED WHEY STORAGE TANKS, 5,000 GAL.
- 77 FUTURE VERTICAL (SILO) CONDENSED WHEY STORAGE TANK, 5,000 GAL.
- 78 CONDENSED WHEY POSITIVE PUMP, 10 G.P.M.
- 79 CLEAN-OUT-OF-PLACE WASH TANKS
- 80 TWO-COMPARTMENT AUTOMATIC CIP UNIT
- 81 THREE-COMPARTMENT AUTOMATIC CIP UNIT
- 81A THREE-COMPARTMENT AUTOMATIC CIP UNIT (WHEY DEPARTMENT)
- 81B, C, D CIP HOOKUP STATIONS
- 82 PROCESS CONTROL PANEL
- 83 CHEESE VAT CONTROL PANEL
- 84 WHEY PROCESS CONTROL PANEL
- 85 RECEIVING AND CIP CONTROL PANEL
- 86 BOILER, 200 HORSEPOWER
- 87 BOILER, 250 HORSEPOWER
- 88 FUTURE BOILER, 250 HORSEPOWER
- 89 BOILER FEED WATER SYSTEM
- 90 COOLING UNITS SUSPENDED FROM CEILING, 12 TONS EACH
- 91 SWEETWATER COOLING UNIT, 115 TONS
- 92 CHILLED WATER COOLING UNIT, 65 TONS
- 93 SWEETWATER PUMP FOR START VATS, 100 G.P.M.
- 94 SWEETWATER PUMP FOR WHEY COOLER, 110 G.P.M.
- 94A SWEETWATER PUMP FOR CONCENTRATE WHEY COOLER, CREAM TANK, 15 G.P.M.
- 95 CHILLED WATER PUMP FOR LABORATORY AND GENERAL OFFICE AIR-CONDITIONING UNIT, 45 G.P.M.
- 96 CHILLED WATER PUMP FOR CULTURE AND MOTHER CULTURE ROOM AIR-CONDITIONING UNIT, 11 G.P.M.
- 97 CHILLED WATER PUMP FOR PARAFFIN, HOOP, LUNCH AND LOCKER ROOM AIR-CONDITIONING UNIT, 118 G.P.M.
- 98 CHILLED WATER PUMP FOR PROCESSING ROOM AIR-CONDITIONING UNIT, 225 G.P.M.
- 99 AMMONIA COMPRESSOR, 25 TONS, 35 HP.
- 100, 101, 102 AMMONIA COMPRESSORS, 100 TONS, 75 HP.
- 103 FUTURE AMMONIA COMPRESSOR, 100 TONS, 75 HP.
- 104 FUTURE AMMONIA COMPRESSOR, 25 TONS, 35 HP.
- 105, 106 EVAPORATIVE CONDENSER, 105 TONS
- 107 FUTURE EVAPORATIVE CONDENSER, 105 TONS
- 108 EVAPORATIVE CONDENSER PUMP TANK
- 109, 110 EVAPORATIVE CONDENSER WATER SPRAY PUMPS
- 111 FUTURE EVAPORATIVE CONDENSER WATER SPRAY PUMP
- 112 AMMONIA RECEIVER 14 IN. BY 12 FT.
- 113 AIR COMPRESSOR, 10 HP.
- 114 COOLING TOWER FOR WHEY EVAPORATOR
- 115 REMOVABLE EQUIPMENT PANEL
- 116 UNIT HEATER SUSPENDED FROM CEILING
- 117 ELECTRIC DISTRIBUTION PANEL
- 118 FIVE TANKLESS CIP STEAM ASSEMBLY ON HOSE AND HOSE REEL
- 119 CITY COOLING WATER RECIRCULATING PUMP
- 120 CHEESE TROWING RACK
- 121 TWO-COMPARTMENT WASH AND STERILIZING SINK
- 122 AIR CONDITIONING AND FILTERING UNIT FOR LABORATORY AND OFFICE
- 123 AIR CONDITIONING AND FILTERING UNIT FOR CULTURE AND MOTHER CULTURE ROOM
- 124 AIR CONDITIONING AND FILTERING UNIT FOR PARAFFINING ROOM
- 124A AIR CONDITIONING AND FILTERING UNIT FOR LUNCHROOM AND LOCKER ROOM
- 125 AIR CONDITIONING AND FILTERING UNITS FOR PROCESSING ROOM (3)
- 126 DRINKING WATER CHLORINATING UNIT
- 127 HOT WATER HEATING AND SUPPLY TANK
- 128 FREON CONDENSING UNIT, 15 TONS, FOR CHEESE DRYING ROOM
- 129 HAND WASH SINK
- 130 EXHAUST FANS
- 131 AIR CONDITIONING UNIT FOR CHEESE DRYING ROOM

FIGURE 1.—Suggested layout for an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

The truck tank washing assembly (118) is located in the shelter. It is mounted on a hoist and monorail to facilitate moving it into and out of the tank manhole and from one truck to another. A hose connects the cleaned-in-place (CIP) unit (80) with any tank having built-in spray-ball cleaning devices. Power-operated overhead doors permit the area to be closed off from the outside during inclement weather.

MILK WEIGHING, STORING, CLARIFYING, AND PASTEURIZING

Milk weighing.—After the raw milk has been inspected, it is pumped from tank trucks into one of the 3,000-gallon vertical weigh tanks (2, 3) and a sample of milk taken for laboratory analysis.

For automatic weighing of the contents of the tank, each tank should be mounted on three legs, equal distance from each other, and a load cell (weight-sensing device) attached to each leg. Each cell incorporates a deflector, and when the amount of milk in the tank changes, the deflection is detected by an electrical differential transformer. The transformer produces an electrical impulse in exact proportion to the deflection in the cell and transmits it to the receiving control panel (85) where a direct reading in pounds of product is given. The accuracy of the load cells should be checked at regular intervals.

Milk storage tanks.—Three 8,000-gallon horizontal tanks (5,6,7) hold raw milk received from weigh tanks. They are equipped with level gages and are located side by side with the front heads extending through the processing room wall to the outside. This location not only eliminates the frequency of cleaning the exteriors of the tanks, since the bulk of the exterior extends outside the building, but also saves floorspace. The tanks are equipped with air-operated sanitary outlet valves. They do not have sight and light fixtures as these fixtures are not needed on a gage-equipped tank that is cleaned in place. Each tank has 80 square feet of refrigerated surface for cooling or holding milk over from one day to another.

Since the milk will be received at about 3.6-percent butterfat content, standardizing clarifiers or extra storage tanks for skim milk to be used for standardizing are not needed.

The raw milk storage tanks are equipped with indicating thermometers. Spray balls, welded into the interior, are connected to CIP hookup station (81).

In front of the raw milk storage tanks is a two-line sanitary header system. This system is used for all movement of product into and out of the storage tanks. One header is used for receiving milk from the weighing tanks or for transferring it from one 8,000-gallon tank to another, and the second to feed raw milk to the clarifier and the HTST (high-temperature, short-time) pasteurizing system. A 180-gallon per minute (g.p.m.) transfer pump (4) is used to transfer milk from one tank to another. Air-operated sanitary valves in the system, controlled manually or automatically from the control panel (82), regulate the flow of milk. To allow space for a two-line assembly and a passageway, an aisle 6 feet wide should be provided.

Clarifying and pasteurizing equipment.—Milk is clarified to remove extraneous material and leucocytes, then pasteurized, and finally transferred through sanitary pipes to the cheese vats.

The clarifier (11) operates at the rate of 20,000 pounds per hour. Milk is pumped through the clarifier with a high-speed sanitary centrifugal pump (10). From the clarifier it enters the HTST pasteurizing system through a balance tank (13). The balance tank is equipped with an air-operated float which modulates a throttling valve on the discharge of the pump (10). This valve controls the flow of milk through the clarifier so as to match the rate of the HTST flow. From the balance tank, the milk travels through the plate heat exchanger (15) by a booster pump (14) and measure flow-timing pump (16). The flow-diversion valve (18) directs the flow of milk after pasteurization.

A water heating and circulating unit (19) provides the hot water needed to heat the milk in the heating section of the plate heat exchanger. The equipment is arranged according to the product flow with adequate space for cleanup and passageway. Wash tanks (79) for manual cleaning of equipment are provided as well as an automatic cleaning setup (81).

The measure flow positive pump (22) is used to pump the milk directly from the HTST unit into the cheese vat, where it is cooled in the cooling section of the HTST unit to 87° F., the cheese setting temperature. The HTST system is planned to process 20,000 pounds of milk per hour, but can be expanded by adding extra plates as needed. Recirculating water pump (119) is in this area also.

The dimensions of this area are 36 by 40 feet.

CHEESEMAKING AREA

Since the top daily receipts of approximately 180,000 pounds are for only a short period of the year, nine 20,000-pound cheese vats (29 through 37) 34 feet long and 5½ feet wide are proposed. The vats have round ends, are insulated and steam jacketed, and have overhead agitators of various speeds. They are spaced with whey-draining vats (41) and whey pump (43) as indicated on the layout. The cheese vat control panel (83) is located nearby. A tunnel underlies the plant so that all utilities may be brought up from below to keep the cheesemaking room as free as possible of items that collect dust or are adversely affected by strong chlorine fog. The air-conditioning and filtering units (125) for the processing area are located here. Starter for setting the cheese is stored in a 300-gallon tank (20). The cheese utensil rack (120) and the two-compartment wash and sterilizing sink (121) are also located in this area.

The automatic curd milling, salting, and weighing machine (45) consists of the following parts:

1. A curd mill of the reciprocating cutter-box type; its speed can be regulated to suit the volume.
2. A hydraulically driven vibrator.
3. An elevating belt-type conveyor (44).
4. A salt apportioning apparatus consisting of a weighing conveyor carried by a sensitive balance mechanism operated by electronic controls and a variable speed electric motor which drives a metering wheel in the outlet of the salt hopper.
5. A revolving mixing drum with an electrically operated discharge gate.
6. A hoop conveying assembly incorporating a pushrod-and-pawl type of conveyor and scales provided with a proximity switch.

The machine is L-shaped and occupies a space about 36 feet long in one direction and 12 feet long in the other. It is approximately 3 feet wide. Its height at the tallest point is 10 feet 11 inches.

Five stainless steel cheese presses (46) 34 feet long, each holding two rows of cheese, are provided. These presses are approximately 37 inches wide. The rated capacity of the presses is as follows:

	Units
Cheddars	60
Twins	130
Daisies	178
20-pound prints	204

The pressure needed is obtained by double-acting sanitary hydraulic cylinders motivated by compressed air controlled by pressure-regulating valves.

A room 90 feet by 130 feet would house the milling, salting, and hoop-filling equipment, the cheese vats, the starter storage tank, and the cheese presses. Whey-separating and whey-cream-handling equipment are usually located in this room; however, recent information on bacteriophage control indicates that these items should be placed in the whey-condensing room along with the whey storage tanks.

STARTER ROOMS

The starter area is completely isolated from the rest of the plant as a precaution against contamination of cultures. It is located at the corner of the building adjacent to the laboratory and 40° F. storage room. Two doors open onto the enclosed dock. One provides access to the laboratory and the other to the powder storage room. An outside door is located at the end of the enclosed dock for the convenience of the starter.

The area is 30 feet wide and 40 feet long and is divided into a series of rooms. The entry room, a dressing room, a fogging room, and a storage room cover a combined area of 130 square feet. A vestibule and lavatory occupy 40 square feet. The vestibule has four doors—one to the fogging room, one to the lavatory, one to the mother culture room, and one to the bulk culture processing room. A room 20 ft. by 13 feet, divided in the middle, opens off the bulk culture room. It is used in part for storage of nonfat dry milk solids used for making culture, and in part for mixing powder and water to make a 12-percent solution. The powder-mixing funnel and pump assembly (23) are located here.

The bulk starter processing room is approximately 20 feet by 27 feet and contains two 300-gallon vacuum pressure stainless steel culture vats (24, 25), leaving enough floorspace for two future vats (26, 27). The centrifugal culture transfer pump (28) is located between the two culture vats. A sink (129) is also in this room.

The mother culture room is 10 feet by 23 feet. It is equipped with autoclave, incubator, refrigerator, laboratory desk, equipment for acidity tests, and the usual laboratory glassware needed for culture handling.

The entire area is air conditioned (123) to maintain a temperature of 70° F. The air is purified and is maintained at a pressure slightly higher than the outside so that any air leakage will be to the outside of the room.

The room is kept locked at all times; only the starter is permitted access.

HOOP-WASHING AND STORING AND PRINT-WRAPPING ROOM

This room is adjacent to the drying and paraffining rooms. A washer (49) for cleaning the hoops and a conveyor pan washer (48) are located here. The hoops come into this room on an overhead conveyor (50) and are placed on a dumping table (51). They then move on the stainless steel mesh-covered conveyor belt through the hoop washer, a stainless steel unit similar to a restaurant dishwasher. The first compartment contains a detergent solution which is a dilute nonfoaming organic acid. The temperature of this solution is automatically held at 160° F. The cleaning solution is sprayed onto the hoops from nozzles by a high velocity pump. In the second compartment, the hoops are sprayed with 145° water.

After the hoops are cleaned, some are stored until needed on stainless steel portable skids especially made for this purpose. The hoops that are needed immediately are returned to the cheesemaking room on the overhead conveyor (50).

A belt conveyor (52) in the room moves the cheese prints into the print-wrapping machine (54) and the boxing machine (55). Round cheeses are moved by the conveyor (53) to the drying room.

CHEESE DRYING AND PARAFFINING ROOMS

The equipment in these rooms is used for drying the various round cheeses after they have been dehooped in the hoop-washing and storage room. The cheese moves into the room on a belt conveyor and is placed in the box lids. These lids are then placed on portable shelves (56) constructed of angle iron welded frames with five black iron painted shelves 52 inches long and 36 inches wide. The bottom shelf is 6 inches from the floor with 16 inches open space between shelves, making an overall height of about 75 inches. The shelves are moved with fork-lift trucks.

For the daisies and twins, removable shelves are placed between the permanent shelves at 8-inch spacings. This is not necessary for the cheddars.

One portable shelf unit is needed for each of nine vats of cheese for 4 days, making a total of 36 units. This arrangement will provide a limited degree of flexibility. Cleaning is no particular problem with the use of these shelves as an occasional hosing with hot water is sufficient.

Air-conditioning and filtering units (124, 131) are provided for the paraffining and drying areas.

After the cheese is dried, the shelves, or racks, of cheese are moved by lift trucks to the paraffining room. The cheese must be coated with 235° F. paraffin to prevent loss of moisture and to protect the surface from mold growth. A paraffin tank (57) 24 inches wide, 24 inches deep, and 78 inches long, with an exhaust hood (58) is provided for this purpose. This tank uses a power-driven mechanism for elevating the cheese and dipping it into the hot paraffin. The paraffin is heated by steam coils; its temperature is automatically controlled.

After paraffining, the cheese is moved to the table and scales (59) where it is boxed and weighed; it is then placed on pallets (60) on the racks and taken to the 40° F. storage room. The empty racks are returned to the drying room. Storage space is provided in the paraffining room for a reserve supply of pallets.

CHEESE STORAGE ROOM

Provision should be made for storing approximately 30 days' production of cheese. Since nine vats of cheese will be made 2 days each week and eight vats 4 days, the total weekly production will be 50 vats. The 30 days' production will constitute $4\frac{1}{3}$ weeks or 216 vats, requiring 216 portable shelf units and pallets.

The pallets are 48 inches long and 43 inches wide. This width is used to permit loading two pallets side by side in a refrigerated semitrailer.

To provide proper air circulation around the cheese, 5 feet of space is allowed for each row of pallets. The pallets are stacked two high in seven stacks, or 14 pallets in a row. To store 30-days' production, or 216 pallets, would require 15 rows and six pallets in the 16th row. The rows are 28 feet long, which leaves 12 feet for aisle space in front. In the center of the room, a strip 10 feet wide and 40 feet long is left vacant for aisle space. The total space required is—

	Square feet
16 rows of pallets, 28 feet long and 5 feet wide	2,240
Aisle space in front, 12 feet by 120 feet	1,440
Aisle space in center, 10 feet by 28 feet	280
Total	3,960

Total space provided in the plan is 4,400 square feet.

Double electric doors 7 feet high permit lift trucks to enter the room from the drying and paraffining room, and two such double doors open from the storage room to the enclosed dock. The room is also provided with eight cooling units (90) suspended from the ceiling.

DRY STORAGE ROOM

Much of the area in the dry storage room (1,600 square feet of floorspace) will be used for storing pallets of empty cheeseboxes, salt, wrapping supplies, washing powders and liquids, farm supplies, nonfat dry milk solids, and miscellaneous supplies, all delivered by truckloads.

Salt will be received in 30,000-pound lots. Bags of salt will be piled three to a tier and eight bags high, or 24 to a pallet. Counting the 13 pallets needed for a load, plus five pallets to be kept on hand as a safety margin, 18 pallets of salt will be stored in the room. Pallets are stacked two high.

Total square feet required: $\frac{16}{2} \times 18 = 144.$

Cheeseboxes

a. Cheddar boxes—16-inch diameter × 14-inch height, nine to a tier, five high = 45 boxes per pallet. A truckload of 810 boxes requires 18 pallets. Ten-pallet reserve supply. Pallets stacked two high = 14 stacks. Total square feet required = 16 × 14 = 224.

b. Daisy boxes—15-inch diameter × $5\frac{1}{2}$-inch height, nine to a tier, 13 high = 117 per pallet. Truckload of 2,340 boxes requires 20 pallets. Ten-pallet reserve supply. Pallets stacked two high = 15 stacks. Total square feet required = 16 × 15 = 240.

c. Twins use the same size of box as the cheddars. Total square feet required = 224.

d. 10-pound prints—This cheese requires an outer box in dry storage. One pallet will hold 1,600 outer boxes, 48 inches high. One month's needs plus 1 week's reserve. 1,080 boxes used per week = 5,400 boxes for 5 weeks. Four pallets will be needed, stacked two high. Total square feet required = 32.

Cleaners and sanitizers

These items are purchased in truckloads. One truckload would be:

32 drums general cleaner
12 drums sanitizer
28 drums acid

Four drums per pallet = 18 pallets. Fourteen pallets reserve supply = 32 pallets. Pallets stacked two high = 16 stacks. Total square feet required = 16 × 16 = 256.

Farm supplies

Washing powder, liquid acid, spray, dairy cattle feed. Requires 2 pallets or 32 square feet.

Dried skim milk

Needed per week. Twelve 100-pound bags. Every other week delivery to maintain freshness. Twelve bags reserve supply. Twelve bags per pallet. Three pallets with one stack two high. Total square feet required = 32.

Summary of floor space needed for dry storage room:

	Square feet
Salt	144
Cheeseboxes:	
Cheddars	224
Daisies	240
Twins	224
Prints	32

Cleaners, sanitizers	256
Farm supplies	32
Dried skim milk	32
Aisle space	416
Total	1,600

Certain items of equipment that need to be moved into or out of the plant can be taken through the storage room. If more convenient, large items can be taken through a removable panel (115) in the wall at the end of the tanker-receiving shelter. Doors, 7 feet wide, to the storage room are electrically operated. The room is provided with a unit heater (116) suspended from the ceiling.

LOADING DOCK

An enclosed loading dock 10 feet wide runs 110 feet across the front of the 40° F. cheese storage room. It is 54 inches above ground level. Electrically operated rollup doors directly opposite the two load-out doors in the cooler will permit rapid loading of trucks with the cheese that is moved out each day. The hall along the dry storage room and hoop-washing room connects with the loading dock.

Shipping containers, salt, chemicals, and other supplies will be received at the door opening to the hallway.

BOILER ROOM, REFRIGERATION ROOM, AND SHOP

These rooms are located outside the main plant in the building that houses the whey-disposal equipment. One person per shift will operate all units housed in this building. An underground tunnel will carry water, power, steam, and refrigeration and whey lines to the tunnel of the main building.

Located in this area are the following items of equipment:

Boiler room—35 feet by 33 feet

One 300-hp. boiler (86)
One 250-hp. boiler (87)
Boiler feed water system (89)
Incoming water-chlorinating unit (126)
Hot water heating unit for sinks and water hoses (127)
Exhaust fans (130)
Removable equipment panel (115)

Refrigeration room—35 feet by 60 feet

One 25-ton ammonia compressor (99)
Three 100-ton ammonia compressors (100, 101, 102)
Two 165-ton evaporative condensers (105, 106) (located outside building)
One 24-inch by 16-foot ammonia receiver (112)
One 113-ton sweetwater cooling unit (91)
One 198-ton chilled water cooling unit (92)
One 15-ton Freon condensing unit for the cheese drying room (128)
Sweetwater pumps (93, 94, 94A)
Chilled water pumps (95, 96, 97, 98)
Sump tank for evaporative condensers (108)
Evaporative condenser water spray pumps (109, 110)
One 10-hp. air compressor (113)
Unit heater suspended from ceiling (116)
Electric distribution panel (117)

Shop—20 feet by 25 feet

The shop for repair of equipment is located adjacent to the refrigeration room. Work benches, repair tools, and mechanical supplies are located here. Exhaust fans (130) are located along the outside wall of the room.

OFFICES

The following offices are needed:

Superintendent's and engineer's office.—The plant superintendent and maintenance engineer share the same office because of the closeness of their work. It is located near the important processing areas and contains 363 square feet. It is equipped with desks, chairs, correspondence files, and blueprint cabinet. One master station for the intercom system is located here for the necessary intraplant communication. Large glass areas are provided on one side for easy plant supervision. The office opens into a 195-square-foot hallway connecting the plant and an outside entrance.

Fieldman's office.—This office is adjacent to the superintendent's office and contains 154 square feet. It is connected by a hallway to both the superintendent's office and the laboratory.

General offices.—Included in this general area are the offices (634 square feet), vault (97 square feet), women's lounge and restroom

(145 square feet), men's room (96 square feet), the viewing and reception area (871 square feet), and the manager's office (234 square feet). The entire area is air conditioned (122).

LABORATORY

The laboratory covers an area of 634 square feet and is located to the right of the main entrance. It is air conditioned and the temperature is maintained at 72° F. The laboratory is divided into two sections, one for bacteriological control work and the other for chemical tests. The equipment needed to perform fat and acidity tests, sediment tests, moisture determinations, freezing point determinations, and whey solids tests are available in the chemical section. The bacteriological laboratory contains the glassware and media necessary to perform the standard procedures for qualitative and quantitative microbiological determinations, and tests for antibiotics and bacteriophage. An autoclave, flowing steam sterilizer, and microscope also are provided. Both laboratories have desks, tables, chairs, bookcases, filing cabinets, and cupboards for supplies.

PLANT LOCKER AND RESTROOMS

The plant's restroom for men workers is near the plant entrance. It is intended that only plant workers will use this room. Milk haulers and general service visitors will use the men's room adjacent to the lunchroom.

The 986-square foot area contains toilets, lavatories, clothes lockers, first aid facilities, and showers. Women plant workers will use the women's restroom adjacent to the lunchroom. This room is equipped with clothes lockers, first aid kit, chairs, a cot, and an air-conditioning and filtering unit (124A).

LUNCHROOM

The lunchroom, containing 385 square feet, is located to the right of the employee's entrance. Since most of the workers will bring their lunches, this room contains tables, chairs, and vending machines for dispensing milk, hot coffee, soft drinks, and candy bars. A rack for current trade magazines is provided. A bulletin board to carry announcements of general interest and importance to company employees will be mounted on one wall. The employees' timeclock is located in the hallway at the entrance to the lunchroom.

WHEY-HANDLING AREA

The equipment for separating and condensing the whey is located in a separate building, which also houses the refrigeration and boiler rooms and shop.

One room, 36 feet by 42 feet, has alcoves for a 4,000 gallon vertical (silo) storage tank (63), a 16,000 gallon vertical (silo) storage tank (64), and two 6,000-gallon vertical (silo) storage tanks (75, 76). These silo tanks are actually located outside the building but are connected with the inside by alcoves. This room also contains two whey pumps, 20,000-pounds-per-hour (65, 65A), a 20,000-pounds-per-hour whey separator (67), a 20,000-pound-per-hour whey clarifier (66), a 300-gallon whey cream cooling and storage tank (68), a 25-g.p.m. whey cream pump (70), a 20,000-pound-per-hour whey vapor heater (62), a 20,000-pound-per-hour whey double-effect recompression evaporator (72) equipped with a 3,000-pound-per-hour condensed whey discharge pump and a cooling tower water return pump, a 20,000-pound-per-hour tubular preheater (71), a cooling tower (114) for the whey evaporator (located outside the building), a 3,000-pound-per-hour condensed whey cooler (74), a whey plate heat exchanger (61), a 100-g.p.m. condensed whey pump (78) for loading bulk tank condensed whey hauling trucks, a three-tank CIP system (81A), and a whey process control panel (84).

A clarifier is included in this system to reduce fat loss in separating whey cream.

A storeroom, approximately 15 by 25 feet, has a 5- by 8-foot men's room in one corner. The storeroom will be used for storing chemicals, janitor supplies, reserve items of equipment, sanitary valves, pipelines, and plumbing and electrical supplies.

Arrangement of Plant Components

In planning a cheddar cheese plant the various components should be arranged to provide for efficient processing and to minimize chances of bacteriophage contamination of starter or cheese curd. To accomplish this, the cheesemaking operations are located in the center of one building with no outside doors or windows, the starter room is isolated at one corner of this building close to the cheese vats, and the whey-processing operations are in a separate building.

The arrangement of the processing areas provides for the receiving, storage, and processing of milk to be carried out at one end of the building; the cheese setting, cutting, cooking, cheddaring, milling, salting, and hooping in the center; and the cheese drying and paraffining between the cheesemaking room and the cheese storage room. This arrangement provides an uninterrupted flow of product from the milk-receiving room through the various processing steps, to stacking of the finished cheeses in the storage room.

Locating the laboratory and the offices of the superintendent, the plant engineer, and the head fieldman adjacent to the main offices brings the administrative personnel together. They can confer without the need of traffic through the plant yet have close contact with the processing operations in the plant.

Efficient flow of the product through the plant is further expedited by the use of a single-floor design and the use of pallets for the dry storage of supplies and the finished cheese. An overhead conveyor system permits the mechanical handling of the hooped cheese.

The lunchroom and locker room are conveniently located for the workers entering and leaving the plant and for use during working hours. These rooms are sufficiently removed from the processing area to prevent a sanitation problem.

The various processing components of the plant are arranged to minimize the distance milk must travel as it passes through the cheesemaking process. This arrangement also provides for workers to change job assignments with minimum delay.

The compactness of the arrangement of the milk-receiving, storing, pasteurizing, and cooling equipment makes automation feasible with mimimum labor. The arrangement of the cheese vats in relation to the automatic milling machine and the cheese presses and the use of an overhead conveyor make curd handling efficient.

The dry storage room is conveniently located for serving the cheese room with needed supplies, such as salt, coloring (if used), wrapping materials, cleaning materials, and containers.

The cheeses leave the presses in hoops on conveyors that pass directly to the hoop-washing and storage room, where they are transferred to conveyors that move them to the drying room. This system makes rapid handling of the cheeses and hoops possible with a minimum of labor.

The location of the paraffining room between the drying and the cheese storage rooms allows a straight-line movement of dried cheese through the paraffining treatment into the storage room without interfering with any other process being carried on simultaneously in the cheesemaking area.

Grouping the whey-processing operations, the repair shop, the boiler room, and the refrigeration room in a separate building is desirable not only for sanitary reasons but also for making possible one-man supervision of all these operations. The various processing and CIP control panels for the machines are located close to them, thus providing simplicity of control. Since the condensing operations need a large amount of steam and water, the vacuum pan should also be located here.

The plant incinerator is outside the rear door to the covered dock, convenient to both buildings.

The Plant Site

The manufacture of cheese is usually concentrated in the rural sections of the country where there are large numbers of dairy cattle but limited demand for milk for market milk and ice cream manufacture. Ordinarily, a site near a small town is chosen to insure the availability of the necessary supply of labor. Suitable power and an ample supply of good water are important. Unless city sewage is available, the soil must be suitable for the proper functioning of a disposal plant.

Locations near industries that produce objectionable odors or that attract rodents or flies should be avoided.

The type of both surface and subsoil will affect the cost of building. The most satisfactory base for low-cost foundation construction is either gravel or soft rockbed with enough grade to provide good drainage.

The land area should be large enough to provide ample space for driveways, employee and visitor parking, and the handling of large trucks. Enough space should be available for simple landscaping in front of the building.

Figure 2 shows the suggested site for the cheddar cheese plant. The area is 1,361 by 800 feet and comprises about 2½ acres. A site of this size provides ample space for future expansion of the cheese operation and the possible addition of some other type of processing plant of agricultural products.

The site should be located on a main highway. Such a location is vital in the hauling of heavy truckloads of milk and supplies and the shipping of cheese. It is also desirable for advertising.

There is a 40-foot entrance to and exit from the area surrounding the plant. The entire area around the plant should be surfaced with concrete or hardtop and sloped to drain. The area on the sides and rear of the site should be enclosed with a high steel-wire fence. A 120-foot clearance between the sides of the building and the edge of the plant area provides ample space for parking cars and maneuvering trucks. Ample room is also provided at the rear and in front of the building for trucks to pass. Space for a limited amount of landscaping in front is provided.

Provision for Plant Expansion

In planning means of handling a doubled plant capacity, lengthening the workday should be considered so as to get maximum use of the equipment. If this were done, present facilities, for the most part, would be ample, though some additional items would be needed.

Additional raw milk storage facilities would be needed. One 8,000-gallon storage tank would suffice, provided raw milk deliveries could be extended through the afternoon.

Another dry storage room and cold storage room would be needed. These facilities could be best located in an extension of the building, as shown on the layout. A 25-ton ammonia compressor (104) would be added to handle the cold storage room addition.

With the rapidly growing popularity of block cheese, all the additional cheese probably will be put in 40-pound blocks. Thus a drying room would not be needed and the curd-handling operation would be simplified, resulting in increased production per man-hour.

Four more double-row cheese presses (47) and more pallets would be needed, and the starter room would need two additional 300-gallon culture vats (26, 27).

No additional equipment would be needed for the whey-handling unit since pickup of the whey cream and whey concentrate could be made twice as often, nor would additional offices be needed.

A less economical procedure would be to operate with enough additional facilities to handle twice as much milk in approximately the same length of time. Again assuming that the added volume would be made into blocks, this would necessitate installing additional equipment or replacing present equipment with items of greater capacity or changing procedures as follows:

1. Two 8,000-gallon raw milk storage tanks (8, 9).
2. A 14,285-pound-per-hour cold milk clarifier (12).
3. Three 20,000-pound-cheese vats and agitators, making a total of 12 (38, 39, 49).
4. Three whey-draining tanks (42).
5. Four cheese presses (47).
6. A dry storage room.
7. A cold storage room.
8. Two 300-gallon starter vats (26, 27).
9. A 300-gallon bulk starter storage tank (21).
10. By changing the cheese vat filling schedule from 1 hour to 35 minutes per vat and by increasing the capacity of the HTST unit by adding enough plates to handle 34,285 pounds per hour, the pasteurization needs would be provided. The length of the holder tube (17) would be increased.
11. Adding a third effect to the present 20,000-pound-per-hour whey evaporator (72) would increase the capacity to 31,000 pounds per hour (73), which is the rate the whey would be available.
12. Enlarging the plate cooler for the condensed whey from its present capacity of 3,000

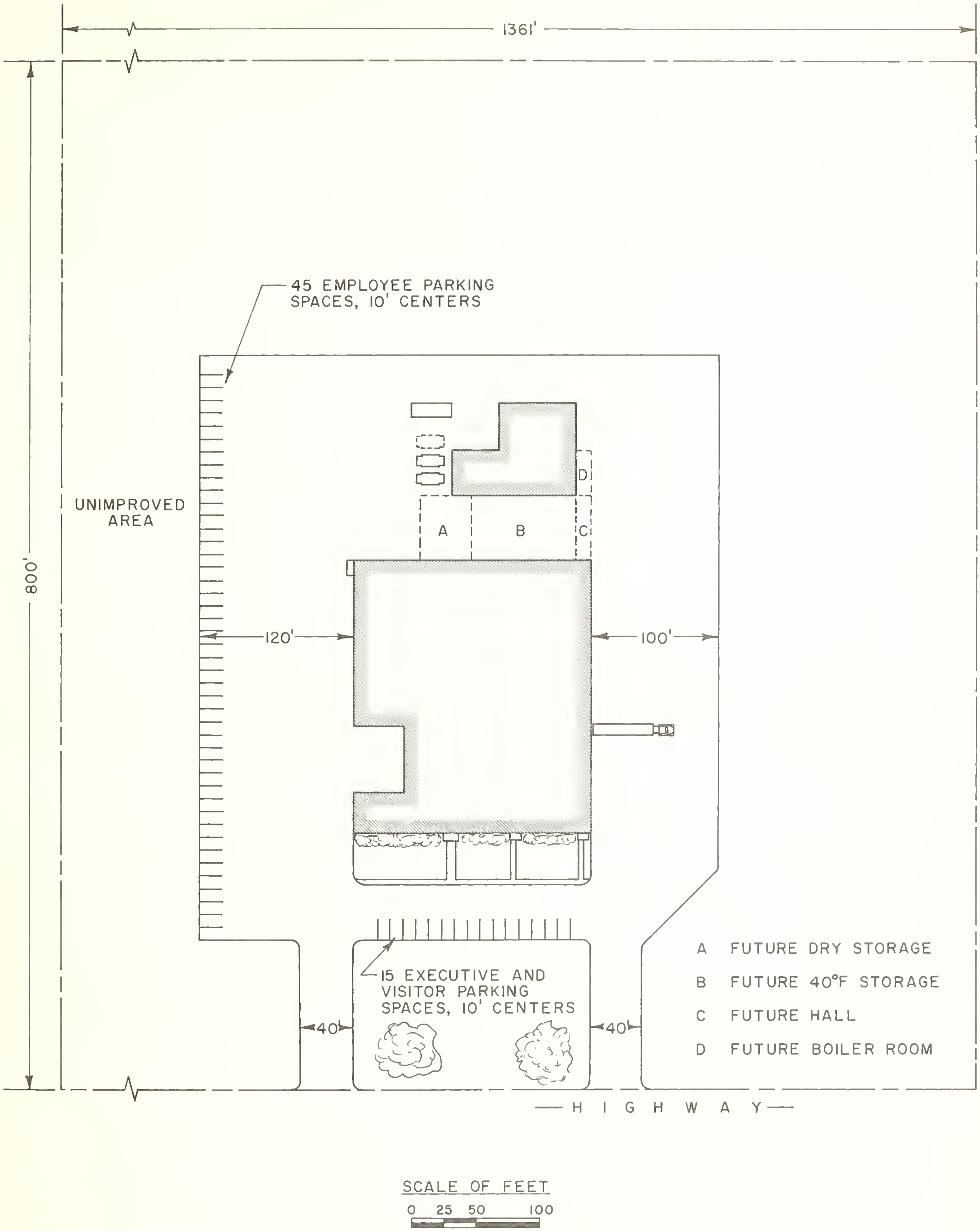


FIGURE 2.—A suggested layout for the site of an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

pounds per hour to 4,600 pounds per hour by adding additional plates.

13. Replacing the present 20,000-pound-per-hour separator with a 40,000-pound-per-hour one, which would be operated at 30,000 pounds per hour.

14. A 300-gallon whey cream cooler and storage (silo) tank (69).

15. Adding another 6,000-gallon condensed whey storage (silo) tank (77), as the present two would lack 1,650 pounds capacity on 2 days a week during the peak season.

16. The raw whey plate heat exchanger would be adequate, as the maximum flow to the whey-processing area would not exceed 60,000 pounds per hour.

17. Additional pallets.

18. Increasing the vapor-line heater (62) to 31,000 pounds per hour.

19. Increasing the tubular preheater (71) to 31,000 pounds per hour.

20. A 300-hp. boiler (88).

21. A 25-ton ammonia compressor to handle the additional 40° F. cold storage room.

22. Additional cooling sections to the chilled water cooling unit (92).

23. An evaporative condenser spray pump (111).

24. A 100-ton ammonia compressor (103) and a 165-ton evaporative condenser (107) to handle the chilled water cooling unit. This is in excess of the size required, but the existing equipment should be matched so that standby capacity would be available.

HOW THE PLANT OPERATES

The major operating cycles involved in manufacturing cheddar cheese are (1) receiving and processing milk, (2) making the cheese, (3) preparing cultures, (4) handling whey, (5) cleaning equipment, and (6) loading out.

Receiving and Processing Milk

Raw milk is received at the plant in 3,000-gallon tank trucks and transferred to 3,000-gallon weighing tanks (2, 3) by a 180-g.p.m. raw milk receiving pump (1). To perform this duty, the operator connects the receiving hose between the tank truck outlet and the pump. The cover on the tank truck is opened. The weighing tank into which the milk is to be pumped is selected on the "Fill" switch on the control panel (85), and the pushbutton actuated to aline the sanitary valves properly for the flow selected (fig. 3). This type of selector switch with a button actuator is used on several control panels throughout the plant. Pushbutton 1 is pressed, which starts the pump transferring the milk to the weighing tank.

Pushbutton 1 is pulled out from the control panel approximately ¼ inch to start and pushed in to stop. A pilot light located in the middle of the button, shows when the electrical circuit is operating. This type of pushbutton is on all the control panels, except where indicated.

When all the milk has been pumped into the weighing tank, the weight is read by turning the "Tank Selector" to the tank just filled. The weight then appears on the indicator.

The tank trucks are washed by CIP procedures, using CIP unit (80) and spray assembly (118). The unit is mounted on a hoist and monorail to facilitate placing it into the tank truck as well as for moving it from one truck to another. All CIP features and controls are discussed under "Cleaning Equipment."

Since milk is pumped out of the tank truck at the rate of 180 g.p.m., a 3,000-gallon tank truck can be unloaded in 17 minutes. The washing time, using CIP recirculation equipment, is 45 minutes. Allowing 20 minutes for sampling and for hooking up and disconnecting pipelines and CIP return pumps, the plant can handle a 3,000-gallon tank truck in 1 hour and 22 minutes. By overlapping the washing of one truck with the unloading of another, the plant can handle seven 3,000-gallon tank trucks easily in 6 hours (fig. 4).

After the milk is weighed, it is transferred into a storage tank and held until pasteurized by actuating the pushbuttons "Transfer From" and "Transfer To" in the control panel (82) (fig. 5). Raw milk transfer pump (4) is then actuated to transfer the milk into the 8,000-gallon storage tank selected. The pump will not start until the pushbuttons under the tank selector switches have been actuated. After the milk is

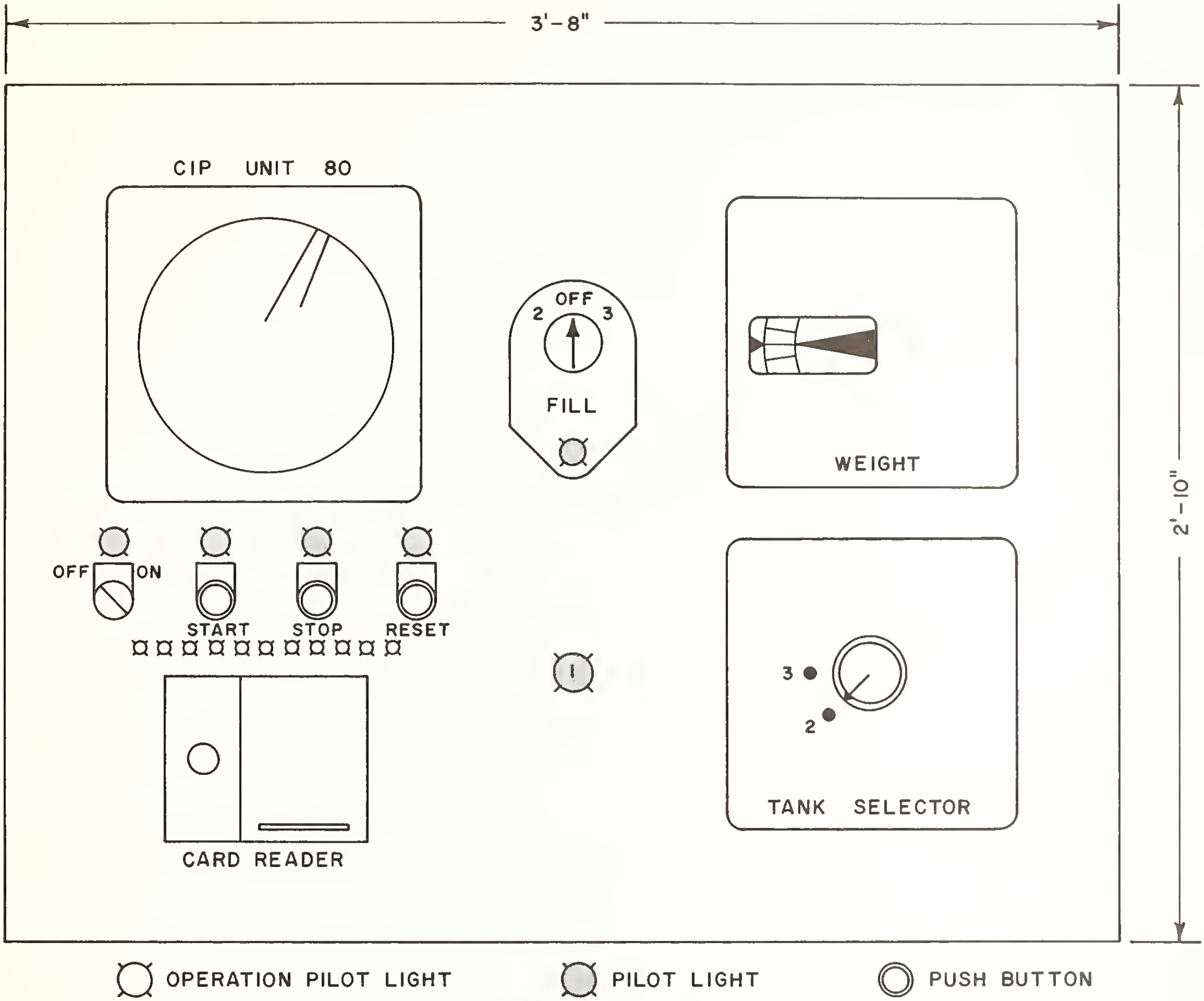


FIGURE 3.—A suggested receiving and CIP control panel for an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

transferred, the pump is stopped by button 4 or by moving a transfer switch to "Off," which breaks the pump circuit as well as the valve circuit.

The milk levels in the three 8,000-gallon storage tanks (5, 6, 7) may be read from the tank gages located on the left side of the control panel. The gages are air operated by a sanitary diaphragm in the tank wall near the bottom. A change in milk level is sensed by the diaphragm, amplified by compressed air, which results in a change in the liquid column within the gage. The gages are equipped with high- and low-level sensing devices which sound a horn at 7,500 and 250 gallons, respectively. The horn may be stopped by pressing the "Horn Stop" button underneath the gages. When the high-level alarm sounds, a red light appears on the visual readout over the tank number. For low level, a green light appears in the visual readout.

The visual readout, located at the top of the control panel, informs the operator as to what his processing situation is at any moment without the necessity of studying all the various switches and gages on the panel. It also informs him which weighing tank (2 or 3) the receiving man is filling. The visual readout is connected to the selector switches electrically so that when a particular function is set up, an abbreviated indication lights up in the opaque glass over the

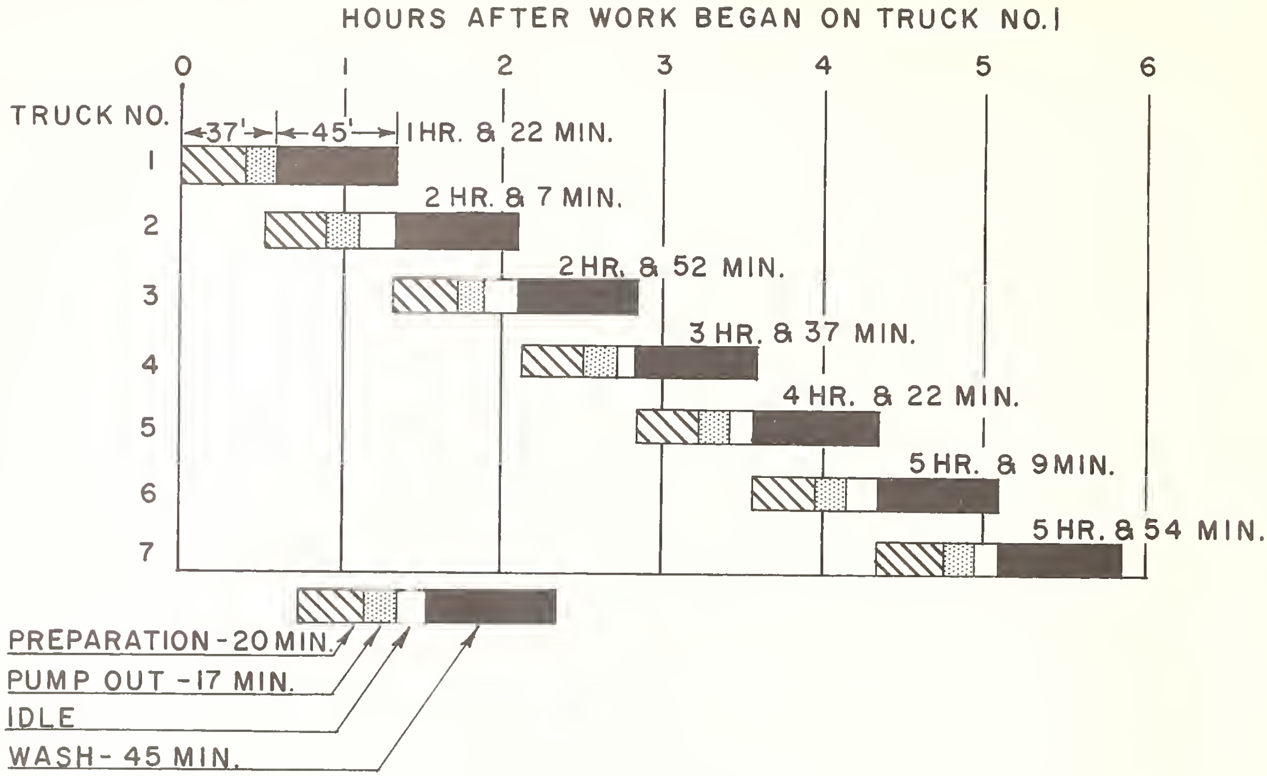


FIGURE 4.—A time schedule for receiving milk and washing tank trucks in a cheddar cheese plant handling 800,000 pounds of milk weekly.

equipment number. Examples of this would be the words "Fill" over (2), "HTST Feed" over (6), "Vat 31" over (15), "Tank 5" over (81) and, "Clean" over (5). Under this condition, the following processes would be taking place:

The receiving man is pumping into weigh tank (2).

The HTST system is using milk from 8,000-gallon tank (6).

The HTST system is discharging into cheese vat (31).

The CIP unit is cleaning 8,000-gallon tank (5).

The 8,000-gallon tank (7) and the 3,000-gallon weighing tank (3) are idle.

The flow of milk and cheese from receiving through filling are shown in figure 6.

Clarification and pasteurization of the milk are performed next. The storage tank which will supply the first milk used is selected on the "HTST Feed" selector switch. The centrifugal pump which feeds the clarifier (11) is actuated until milk appears in the balance tank (13) and is then shut off. This fills the clarifier with milk, which will lubricate the seals while it is being brought up to speed, at which time clarification and pasteurization may begin.

The cheese vat that is to receive the first milk is selected on either of the "HTST Discharge" switches. These two switches are interlocked so that if one switch is already set on a cheese vat the other will not function until the first switch is set on "Off." The HTST system is started by:

1. Starting heat and circulating unit (19) and cooling water circulating pump (119).

2. Turning on steam and cooling water supply valves.

3. Setting HTST (15) recorder-controller on proper pasteurizing temperature (161.5° F.).

4. Setting HTST cooling section recorder-controller on proper cheese setting temperature (87° F.).

5. Setting the "Totalizer" for pump (16) on 20,000 pounds.

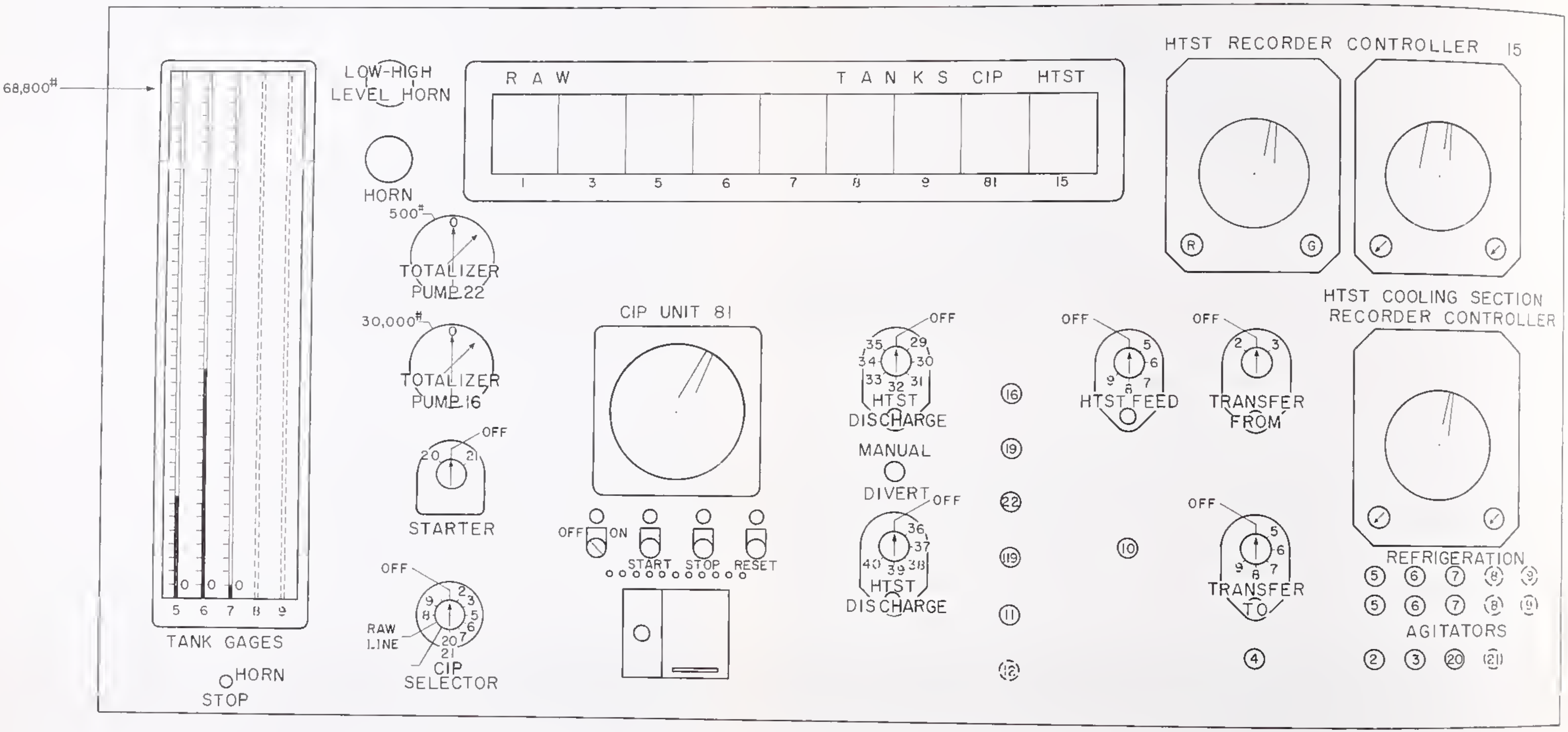


FIGURE 5.—A suggested process control panel for an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

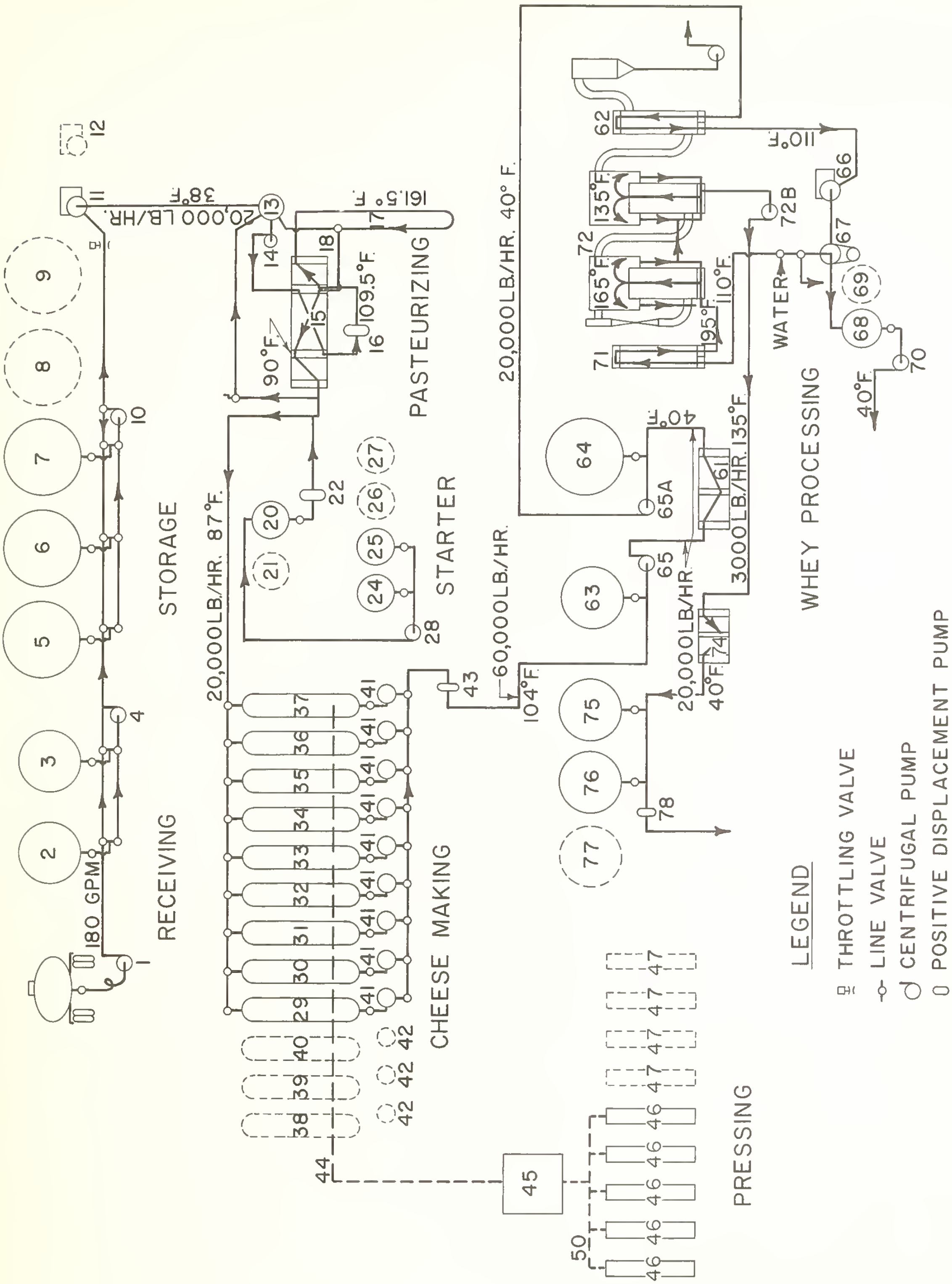


FIGURE 6.—Flow of milk and cheese products from receiving through filling.

6. Starting clarifier feed pump (10) and measure flow pump (16).

The milk will then flow through the clarifier (11) to the balance tank (13). An air-actuated throttling valve on the discharge of the pump (10) controls the flow through the clarifier to the rate required by the HTST pasteurizing system. The measure flow pump (16) will pull the milk through the raw milk side of the regenerator and push it through the remainder of the pasteurizing system to the cheese vat. The milk will be diverted for a moment back to the balance tank (which serves to reintroduce sublegal temperature milk into the system) by flow-diversion valve (18) until the 161.5° F. temperature is reached. When this temperature is reached, the flow-diversion valve changes position causing the milk to flow through the pasteurized side of the regenerating section, the 16-second holding tube, the cooling section, and on to the cheese vats.

The booster pump (14) comes on automatically when the flow-diversion valve goes into forward flow, as the pump is interlocked electrically with the recorder-controller. In addition, a pressure switch in the system prevents the pump from operating if the pasteurized milk pressure in the regenerating section is less than the raw milk pressure. This makes certain that should any leakage in the regenerating section occur, it will be toward the raw milk side.

The instruments located in control panel (82) automatically control the pasteurization temperature and final temperature of milk going to the vats. These temperatures are recorded for use by health regulatory agencies as well as management. After operating a few minutes, the temperatures will equalize at the following:

	°F.
Raw milk in	38.0
Raw milk out of regenerator	109.5
Raw milk out of heater	161.5
Pasteurized milk out of regenerator	90.0
Pasteurized milk out of cooler	87.0

A holder tube (17) is used in the HTST system to hold the milk for 16 seconds at 161.5°F. to insure proper pasteurization. Higher temperatures should not be used because of their detrimental effect on the yields of cheese.

When the flow-diversion valve (18) is changed to forward flow, the "Totalizer" for the measure-flow pump (16) automatically begins to tabulate the amount of milk passing through the system. This instrument tabulates the volume passing through the pump. The measure-flow pump is actually two positive displacement pumps in series, one pump head providing the pressure and the second operating at no pressure drop. Thus, the revolutions traveled by the second pump head are very closely proportioned to the volume of milk passing through the pump. These revolutions are calibrated in pounds on the totalizer.

When 19,000 pounds have passed though the measure-flow pump (16), the totalizer horn sounds, indicating to the operator that in 3 minutes 20,000 pounds of milk will be in the cheese vat. At that time, the operator pushes the "Manual Divert" button, which will momentarily cause flow-diversion valve (18) to divert the milk back to the balance tank (13). While holding the manual-divert valve in, the operator advances the "HTST Discharge" switch to the next vat and, then, releases the manual-divert valve. The milk will then flow into the next cheese vat. The totalizer for pump (16) is reset to "0" and the next vat is filled.

The totalizer horn may be turned off by pushing "Horn Stop."

If the operator fails to depress the manual-divert valve when changing from one cheese vat to another, the milk will pass through a relief valve back to the balance tank. This is not recommended, however, because it creates excessive pressure on the plate heat exchanger (15). It is used only as a safety device.

Making Cheddar Cheese

Starter, a bacterial culture chosen for its cheddar cheesemaking qualities, is stored in a 300-gallon vacuum pressure tank (20). It is forced into the pasteurized milk line leading to the cheese vats at the time the vat is starting to fill by the measure-flow pump (22). The operator sets the desired quantity of starter (1.00 to 1.25 percent, or 200 to 250 pounds) on the totalizer, and the pump is started by pushing button (22). When the correct amount of starter has been added, the pump shuts off automatically and the totalizer is reset to "0" for the next vat. The outlet valve on the starter tank is controlled by the "Starter" selector switch. Opening and closing this valve for each addition is not necessary because the measure-flow pump (22) prevents backflow.

Other features of the control panel (82) include pushbuttons for the tank agitators and for the cold-wall sections on the 8,000-gallon storage tanks (5, 6, 7). These pushbuttons are connected to solenoid valves which admit refrigerant to the cooling sections of the cold-wall tanks.

A strip chart recording thermometer could be used to maintain a 24-hour record of the temperatures of raw milk in the weighing tanks (2, 3) and the storage tanks (5, 6, 7); however, its expense does not seem warranted for a plant of this type, receiving all milk in bulk. Therefore, indicating thermometers are used.

When the first 20,000-pound cheese vat (29) is filled, the cheesemaker adds 60 ounces of rennet, an enzyme, diluted with 10 gallons of cold chlorinated tapwater. This is repeated on subsequent vats (30 through 38) when they are filled. To mix in the rennet, the mechanical agitators are operated the length of the vat three times by turning the agitator start switch on the control panel (83) to "Automatic" (fig. 7.).

The agitator automatically stops after it has traveled the length of the vat three times. As the agitator reaches the end of a vat, it strikes a limit switch which is connected to a stepping-type relay. At the third engagement, the stepping relay will turn the agitator off. Shortly after the rennet is mixed in, the agitator paddles are removed.

CUTTING THE CURD

The proper time for cutting the curd varies from 20 to 25 minutes after adding rennet; it is determined by inserting a spatula into the

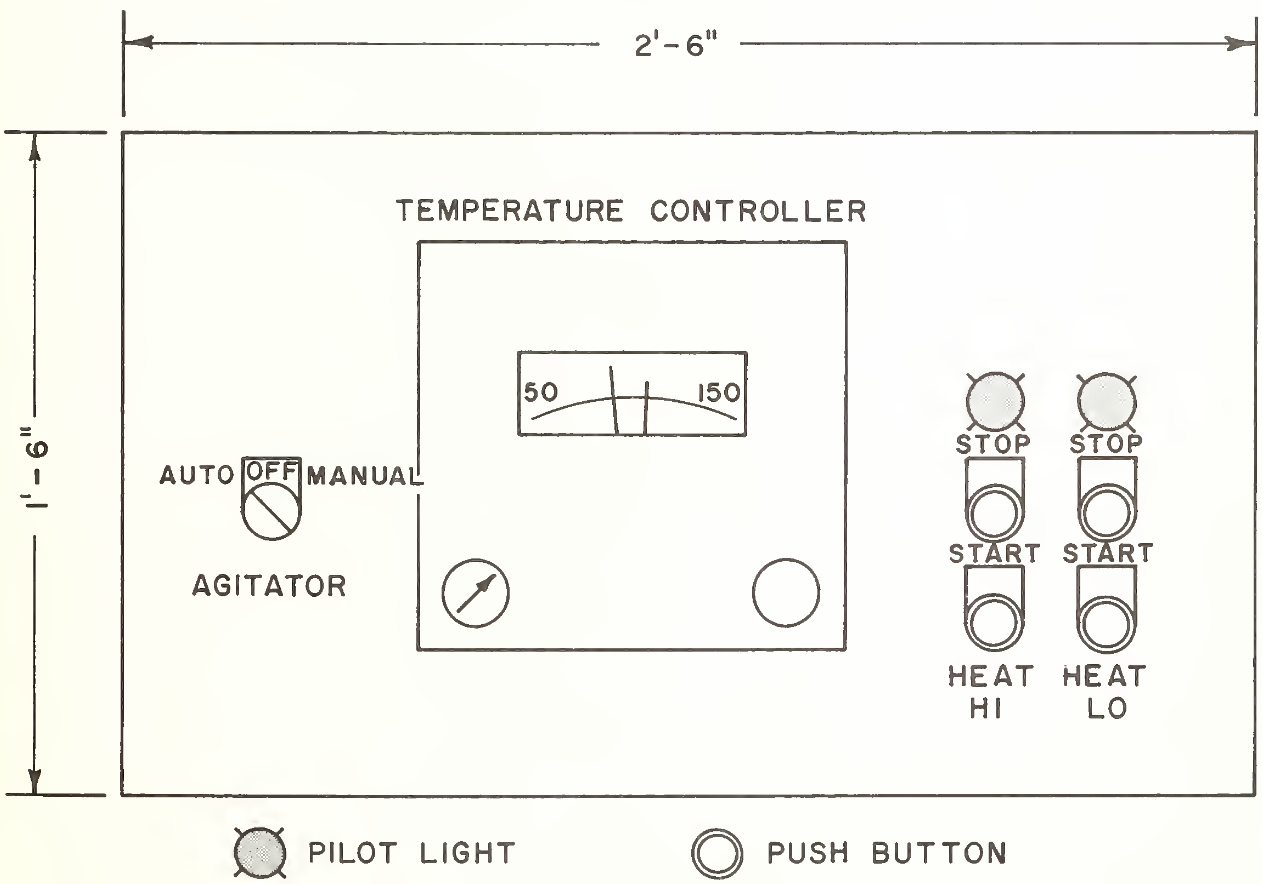


FIGURE 7.—A suggested cheese vat control panel for an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

coagulum at a 45-degree angle and raising it slightly to judge firmness of the curd. Cutting the curd at the right time is essential. If it is cut too soon, excessive fat and curd loss occurs. If cut too late, the curd particles will be irregular, resulting in nonuniform whey expulsion. When the cheesemaker decides the curd is ready, it is cut immediately with curd knives.

A curd knife is a rectangular shaped metal frame with stainless steel piano wires stretched vertically or horizontally. The wire spacing is set to secure the desired size of curd particle (¼ inch). In cutting the curd, two men cut the length of the vat, one using the horizontal knife and the other the vertical knife, drawing them through the coagulum, side by side. After cutting the length of the vat, the knives are reversed to opposite sides of the vat and a return cut the length of the vat is made, finishing a horizontal and vertical cut on each side of the vat. To finish cutting, the curd is cut across the vat with the vertical knife.

Twenty minutes after the curd is cut, whey begins to move from the particles. The slight firmness that has developed permits slow agitation of the curd in the whey. Mechanical paddles are inserted into the agitator shaft, and the agitator switch is turned to "Manual" on the control panel (83) to start agitation. Steam is turned into the vat jacket by pressing the "Heat Lo" button. This admits steam from a line, which will raise the temperature of the contents of the vat 2° F. in 5 minutes. The temperature-controller in the control panel (83) is set for 100° to 104°. The temperature to which the curd is heated will determine the amount of moisture retained in the cheese. At the higher temperature, the moisture content of the cheese will be lower. The moisture content will vary from 35 to 38.5 percent. (The legal maximum is 39 percent.) When the desired temperature is set on the temperature-controller, the steam input will be modulated to maintain that temperature until the steam is turned off by push-button.

MAKING ACIDITY TESTS

Sixty minutes after the curd is cut, a sample of the whey is gathered in a stainless steel cup. From this sample, 9 milliliters (ml.) are pipetted and tested for acidity. The acidity should be between 0.13 and 0.15 percent. Half the whey is then drawn by gravity into the whey-draining tanks located at the outlet valve of each vat. The tanks are 16 inches in diameter and contain an additional strainer. They are of such height that the level of whey is no higher than the level of liquid in the vat, thus preventing overflow during drainage. A positive-displacement pump (43) forces the whey into one of the whey storage tanks.

After half the whey is drained from the curd, the vat strainer is removed and the curd is again agitated for 5 minutes at medium speed. The paddles are then removed; the whey strainer is replaced; and the vat valve is opened. The curd is then pushed with the stainless steel curd rake toward the rear and sides of the vat, forming a trough lengthwise of the vat to facilitate drainage of the whey. The trough should be about 8 inches wide and the curd 4 to 5 inches deep.

A sample of the whey is again taken in a stainless steel cup from the bottom of the vat. A sample of the whey is removed from the cup with a 9-ml. pipette and tested for acidity. This test is made on a stainless steel table in the vat area. At this point, the acidity of the whey should be 0.20 to 0.25 percent. As the whey continues to be expelled from the curd, it accumulates in the whey-draining tank.

THE CHEDDARING PROCESS

The curd is next cut into slabs 18 inches long and 2 inches wide by hand with a cheese knife, the curd being cut from the center of the vat to the sides to produce blocks about 5 inches wide, 4 inches thick, and 26 inches long. Starting at the rear and moving forward, each block is turned on its side with sufficient space between blocks to permit drainage. If the whey does not drain sufficiently from the curd, a sour flavor will be noticeable in the finished cheese. This sour flavor will continue to develop and will result in an off-grade cheese. The block-turning process is repeated until each block has been given a quarter turn four times.

The row of blocks is next cut through the center lengthwise; the cheesemaker then turns each alternate cut block over and places it on top of the one next to it. The blocks are again turned, placing the top block on the bottom of the vat without turning and then flipping the bottom piece end for end and placing it on top. This somewhat tedious process is necessary to prevent uneven evaporation from the curd, since uneven drying will result in nonuniform acidity development and a variation in color, both of which will cause streaks in the cheese.

The next step is to arrange the slabs in tiers three high, placing the top piece on the vat bottom and flipping the other two end for end. Each time, one end of each block is in contact with the vat wall as an aid in retarding evaporation. The three-high stacking is done twice, after which the blocks are stacked four high, using the same precautions to avoid surface drying of the curd.

At this point approximately 1 hour has elapsed since cutting the curd into the 5- by 4- by 26-inch slabs. The four-high tiers are turned twice at 10-minute intervals, after which the whey is again checked for acidity, which at this stage should be 0.50 to 0.60 percent. If the acidity has not reached 0.50 percent, the blocks are restacked until the proper acidity has developed.

The curd particles are now matted together and are somewhat plastic. This change, known as the cheddaring process, is necessary to obtain the proper flavor and body in the finished cheese.

Automation of the cheddaring process has been tried, but at the time of this study no process has been developed that has proved entirely successful on a commercial basis. When a satisfactory method has been perfected, savings in labor will be considerable.

MILLING, SALTING, AND HOOP FILLING

The curd blocks at this point measure approximately 30 by 12 by 2 to 3 inches. They are next placed on 14-inch conveyors (44) located in every other row between the cheese vats. These conveyors move from left to right to another belt conveyor moving at right angles, which picks up the curd blocks and delivers them to the curd milling, salting, and weighing machine (45). These conveyors are equipped with stainless steel belts that are easily cleaned and sanitized.

The cheddared curd is fed into the hopper of the curd mill, and the milled curd falls onto the tray of a vibrator which spreads it evenly on the elevating conveyor. From the top of this conveyor, the curd falls onto the belt of the weighing conveyor. The weight of the curd is translated by the balance mechanism and the electronic controls into a corresponding speed of rotation of the salt-metering wheel and thence into an automatic delivery of a predetermined amount of salt proportional to the weight of the curd. Usually salt is added at the rate of 4 pounds for each 1,000 pounds of milk processed.

The curd and the salt are fed simultaneously into the mixing drum where they are thoroughly mixed. The salted curd is then discharged from the drum into the hoop and dressed with single-service bandages on the scales of the hoop conveying assembly. When the hoop has received the required quantity of curd, a switch in the scale causes the discharge gate to close. After a preset short delay, the pushrod-and-pawl conveyor automatically moves the filled hoop away, brings an empty hoop onto the scales, and the filling cycle is repeated.

An overhead conveyor system (50) brings the washed and sanitized hoops from the hoop storage room to the milling and salting machine, where single-service press cloths are inserted before the curd is added. The same conveyor takes the filled hoops to the cheese presses.

CURD PRESSING

The hoops of curd are placed end to end in one of the four 34-foot double-row cheese presses (46) which are located near the milling and salting machine and parallel to the cheese vats. To permit the added salt to dissolve completely, the hoops remain here under no pressure for a half hour, after which 50-pound gage air pressure is applied for a half hour. Pressure is then released; the hoops are removed; and the single-service bandages are redressed. The cheese is put back into the hoops and returned to the press, where it remains under 50-pound gage air pressure overnight. The next morning, the hoops of cheese are removed from the press and placed on overhead conveyors (50) which take them to the hoop-washing and storage room.

HOOP WASHING AND STORAGE

When the stainless steel conveyor carrying the hoops of cheese reaches the hoop-washing and storage room, it dips down to table height. The hoop is then lifted from the conveyor pan, inverted at the dumping table (51), and the cheese removed. The empty hoop is placed on a conveyor belt which takes it into and through the hoop washer (49).

After the twin, daisy, and cheddar cheeses are removed from the hoops, they are placed on a conveyor and taken into the drying room. They are placed on the portable drying shelves and moved by pallet truck to an assigned area of the drying room.

The print cheese is moved on the belt conveyor (52) from the dumping table through the print-wrapping machine (54) to the boxing table (55).

At times some of the washed hoops will be placed back on the overhead conveyor to be reused. At other times, all of them will be stored on pallets in this area until needed. For nine vats of cheese, nine pallets of hoops of the type needed to match the styles of twins, daisies, cheddars, or prints being made are required. Hoops should not be stored nested but stacked so that air can circulate around them to permit drying.

The overhead conveyor pans travel through a washer after the filled hoops are removed from the conveyor and before the cleaned empty hoop is placed back on the conveyor. The washer sprays the hanging arm and pan with the same kind of acid solution that is used in the hoop washer. This is followed by a warm water rinse at 145° F. The pans are automatically tilted for a distance of 10 feet to allow all rinse water to drain, since the pans have solid bottoms to prevent salty whey from dripping to the plant floor while the hoops are being conveyed from the hoop filler to the cheese presses.

DRYING AND PARAFFINING THE CHEESE

The round types of cheeses are placed on portable shelves (56) and dried for 48 hours at 55° F. and 70 percent humidity. After drying, pallets of cheese are taken to the paraffining room.

The paraffin tank (57) has a power drive for the cheese elevator, which will dip five cheddars, 14 daisies, or 10 twins into the paraffin; there is an automatic shutoff on the upstroke. An overhead hood (58) carries away the vapors.

PACKAGING THE CHEESE

After paraffining, the cheeses are weighed and boxed, with the weight and vat number marked on the box. These boxes are then placed on pallets (43 by 48 inches), all the cheese from one vat (1,930 pounds) being kept on one pallet. One box from each vat is set aside for later inspection. This box is stored in the same room with the pallet of cheese.

After the press cloths are removed, the prints are wrapped with a laminated multilayer of foil and plastic material. A heated press (54) seals the print wrapper to the cheese. All six surfaces of the press are heated by 170° F. oil circulated through the hollow plates of the sealer. The cheese is pressed for 17 seconds to seal the wrapper.

CURING

The wrapped prints and the boxed paraffined round cheese are moved by pallets into the cheese curing room (40° F. storage room) by electrically powered forklift trucks. The cheese is left in the curing room for 30 days before being shipped to the market.

LABORATORY TESTS IN CHEESEMAKING

Samples of producers' milk are tested periodically in the laboratory for fat, bacteriophage, antibiotics, sediment, and possible watering. Periodic checks are also made on the sanitary quality of plant tapwater. A sample of cheese from each vat is checked for fat and moisture content when manufacture is completed. The cheese is held 30 days and then checked again for fat and moisture content before being shipped. At this time, the cheese is graded for flavor, color, body, and texture. Phosphatase tests are made of the milk from each vat set for cheese. An acidity test is made hourly of the whey before and after condensing, and the condensed whey is checked for total solids. Two men will be needed to perform these tests.

Preparing Cultures

The starter (culture) maker begins his workday by changing into clean white clothing and clean rubber boots in his dressing room. Before entering the working area, he passes through the chlorine-fogged room. He will then sample the bulk starter set the previous day for flavor, odor, and acidity. If the acidity reading is in the range of 0.9 to 1.1 percent (starter is made from 12-percent solids skim milk), the worker will cool the bulk starter from 70° to 40° F. with sweet water.

The intermediate culture set the previous day is also sampled for flavor, odor, and acidity. If it is in the same acidity range as that of the bulk starter, the intermediate culture is cooled in the water bath to 40° F. The flask of intermediate culture used for these tests is discarded and not used for bulk inoculation.

For bulk culture, two 300-gallon starter vacuum pressure processors (24, 25) are used. Usually 1 percent of bulk culture will be needed, but this percentage may vary with changing culture activity and changing amounts needed in the milk in different seasons. One-percent inoculation on a peak day of 180,000 pounds would require 1,800 pounds of bulk culture. Two 300-gallon units have been chosen to permit making the starter one day, testing the following day, and using the third day. If a starter is found defective in one vat, the batch is discarded and another immediately set up for testing the following day. This procedure lessens the chance of ruining a day's make of cheese.

About 4 p.m., the operator will have drained the starter storage vat (20) which was filled with culture made 2 days before and will have pumped it into the cheese vats. He will then clean and sanitize the vat, and refill it from the batch he has checked.[2] He will rinse the empty starter processor (24 or 25) with cold water and then clean it with a detergent, following with an acid wash and rinse. Finally, the starter processor will be steam sterilized at 20 pounds pressure for 1 hour.

Immediately after the equipment is sanitized, the starter maker will pump mixed water and nonfat dry milk into the starter processor in such proportions as to make a 12-percent solution. The nonfat dry milk used is low-heat Grade A tested powder especially made for making starter. Water and powder are recombined in a mixing funnel (23). As soon as the required pounds of reconstituted mixture are added, the solution is heated with steam in the processor to 190° F. and maintained at that temperature for 1 hour.

During the 1-hour holding period, the starter maker makes a 12-percent mixture of nonfat dry milk and water in a sterile 5-gallon stainless steel can, using a sterile stirring rod. This is divided between the required number of flasks for intermediate culture plus one for sampling. The flasks are heated in an autoclave at 10 pounds pressure, equivalent to 240° F., for 1 hour. Temperature in the autoclave is then brought down gradually, and the flasks are removed to a water bath where they are tempered to 70°.

Floors of the dressing room, mother culture room, powder mixing room, and bulk culture room are all thoroughly scrubbed and rinsed daily. Just before the starter maker leaves for the day, the rooms are fogged with 500 parts per million (p.p.m.) of chlorine. Then the intermediate culture is inoculated with a fresh sample of commercial freeze-dried culture from a batch of culture that has been pretested for activity and reliability for cheddar cheesemaking. Intermediate culture is then carefully agitated and set in the 70° F. incubator.

Then the starter maker removes the flasks of intermediate culture that were set the previous day and adds the required amount of intermediate culture to the bulk starter processor (24 or 25) containing pasteurized reconstituted nonfat dry milk. The mixture is agitated 5 minutes with the power agitator, temperature is checked to insure setting at 70° F., and the air-conditioning thermostat is checked to make sure the room temperature is 70°. The starter maker locks the door of the starter room when he leaves.

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[2] To check the activity of the culture, 9.5 ml. of pasteurized milk is transferred into a sterile bottle. The milk is tempered to 90° F. and 5 ml. of test culture is added and mixed with the milk. The sample is incubated at 90° for 4 hours, after which the titratable acidity is determined. A lactic acid value of 0.6 to 0.7 percent represents a very active culture; 0.5 to 0.6 percent is an average culture activity; less than 0.5 percent is a slow culture that should be discarded.

Handling Whey

Whey, a prime source of bacteriophage, is handled in a separate building. Workers in this building are not premitted to enter the operating areas of the cheese plant. The outside doors to the working areas of the cheese plant are kept locked at all times.

The whey that drains from the curd collects in the whey draining tanks (41) located near the outlet valve of each cheese vat. This whey contains about 0.25- to 0.35-percent fat and 6.5- to 7.0-percent total solids. Since these solids have enough food value to justify their salvage, provisions are made to separate the fat for cream to be used in buttermaking and to condense the remainder of the solids for making dried whey, which can be used for either human or animal food. This method of whey disposition avoids the problem of stream pollution and the expense of setting up and operating a waste disposal system at the plant.

Since whey is a prime source of bacteriophage, it should be handled in a remote location. Therefore, a pump (43) is provided to move the whey through a 2½-inch sanitary pipeline located in the tunnel beneath the building to the whey-handling plant. Since the rate at which whey is drained from the vats varies, a 4,000-gallon vertical storage tank (63) is used as a surge tank to even out the flow through the whey separating and concentrating process.

Warm whey is cooled to 40° F. to prevent buildup of acidity while in storage. A centrifugal pump (65) passes the whey through a plate heat exchanger (61) which cools the whey first with city water and finally with 34° sweet water recirculated from the sweetwater cooler (91) by pump (94). The whey then passes into a 16,000-gallon vertical storage tank to await further processing.

The air-operated inlet-outlet valves for the 4,000-gallon and 16,000-gallon storage tanks, as well as the pumps, may be controlled from control panel (84) (fig. 8).

To start the separating and evaporating process, the bypass control for the 20,000-pound-per-hour double-effect recompression evaporator (72) is turned to "On" position. This closes the incoming product line to the 20,000-pound-per-hour tubular preheater (71) so that a vacuum may be pulled on the system. At the same time, the whey discharge line from the separator (67) is opened to the floor. The steam jet air ejector is started and the water from the cooling tower (114) admitted to the condenser. The cooling tower water-return pump is started, and the water temperature controller (control panel 84) is set to the proper temperature. When the unit is up to full vacuum, water is admitted to the tubular preheater (71). The temperature-controller for the tubular preheater is set at 195° F. and the steam turned on. The condensate pumps, (62), (71), (72) (control panel 84), are started. The steam pressure controller for the vapor recompressor is set to the proper steam pressure and the steam turned on. At this point, the evaporator will be operating on "Water." The concentrated whey discharge pump is the only evaporator item which remains to be started.

All these functions may be carried out from the control panel (84) except turning on steam to the preheater (71) and evaporator (72), which may be done from valves adjacent to the control panel. These functions are grouped in the upper right-hand part of the control panel.

Centrifugal whey feed pump (65A) is started, forcing the whey at the rate of 20,000 pounds per hour through the vapor-line preheater (62), where it is heated to 110° F., and on through the clarifier (66) and separator (67). The air in the system between the whey feed pump (65A) and the separator is vented to the floor. When the operator notes whey discharging to the floor, he changes the bypass switch to control (71), which shuts off the flow of water to the tubular preheater and closes the valve opening to the floor, thus starting the whey into the tubular preheater.

The 6,000-gallon vertical storage tanks (75, 76) are provided for storing 40-percent total solids whey concentrate before shipping. The proper tank is selected on the control panel (84) by turning the selector switch to "Feed." The city water and 34° F. sweet water are turned on to the concentrated whey plate cooler (74). Sweetwater pump (94A) is turned on. The concentrated whey system is now ready to receive product from the evaporator (72).

A continuous reading refractometer is lo-

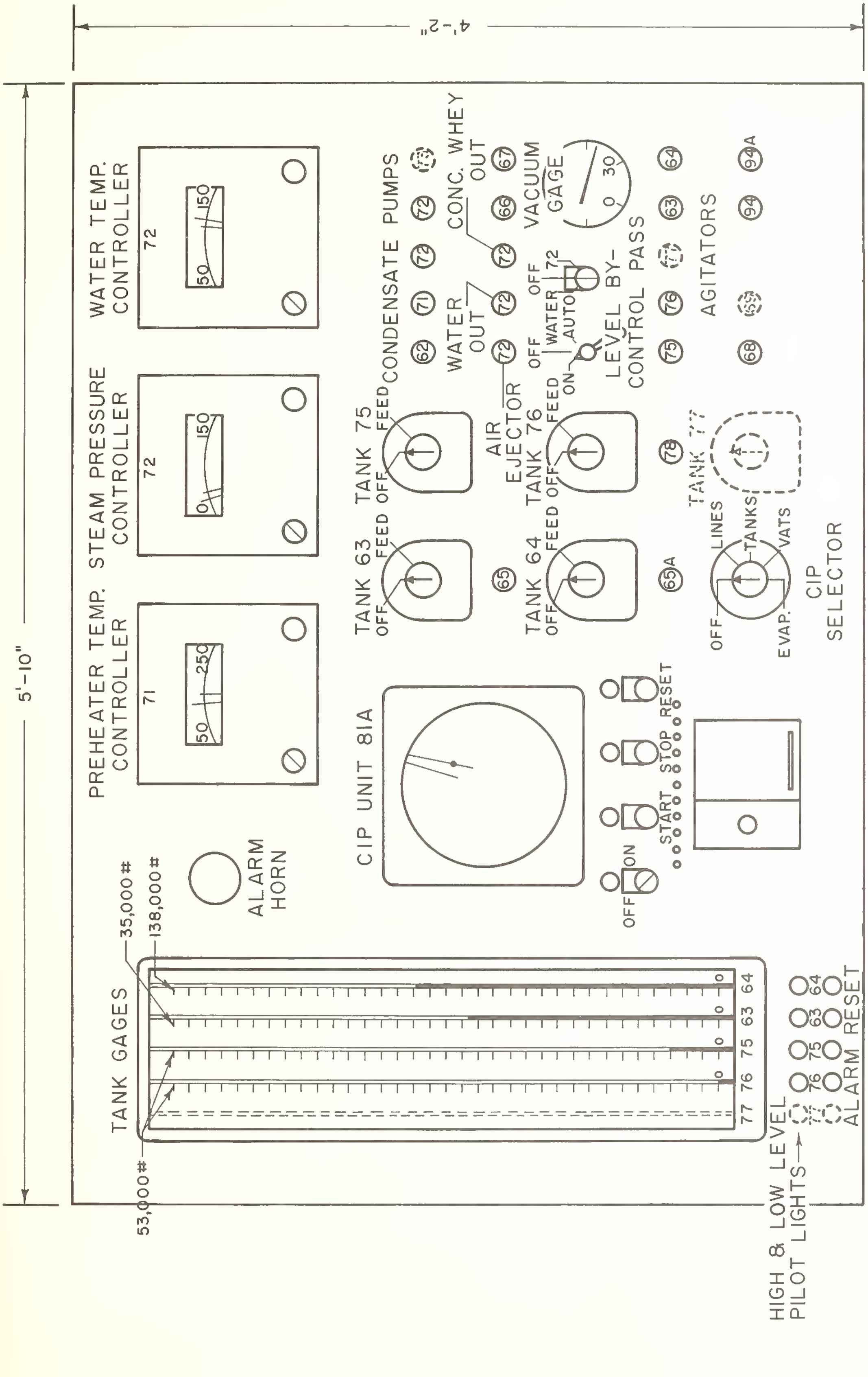

FIGURE 8.—A suggested whey process control panel for an automated cheddar cheese plant handling 800,000 pounds of milk weekly.

cated in the second effect of the evaporator. This device indicates to the operator what the total solids concentration in the second effect is at any time. When the concentration reaches 40-percent total solids, the concentrated whey discharge pump is started. This transfers the concentrated whey through plate cooler (74) to the 6,000-gallon storage tanks. The discharge is adjusted to give a continuous reading of 40-percent total solids. The refractometer is checked periodically by the operator, and the discharge of the evaporator is adjusted as needed. The rest of the operation is automatic and continuous.

The sweetwater inlet valve to the 300-gallon whey cream cooling and storage tank (68) is opened. This will cool the cream to 40° F. When the cream level is above the agitator, the agitator is turned on by pushbutton (68).

The whey processing system is now in full operation.

A centrifugal whey cream pump (70), 25 g.p.m., and positive displacement whey concentrate pump (78), 100 g.p.m., are suggested for pumping products to tank trucks that are adjacent to the processing room.

Tank gages for the whey storage tanks are located on the left side of the control panel (84). These gages will enable the operator to know what the storage situation is at any moment. The gages are equipped with high- and low-level alarms which sound the alarm horn and turn on the pilot lights located just below the tank gage. The alarm may be acknowledged and turned off by pushing the "Alarm Reset" button just below the gage. These gages operate on the same principle as those in control panel (82) (fig. 5).

A visual readout is omitted from the whey-processing control panel since there is single usage of all equipment except the 6,000-gallon condensed whey storage tanks. The operator does not need to be informed quickly as to the status of his operating equipment since he does not have to decide on the item of equipment to use next.

The CIP unit (81A), the controls of which are located in control panel (84), is the same type as that used for the milk processing equipment. Its use and operation are discussed elsewhere.

The double-effect recompression evaporator provides 3 pounds of evaporation for each pound of steam consumed. The selection of this unit depends upon the balance of operating cost (additional condensing water and fuel required for steam) against capital investment (added cost of double-effect recompression evaporator over single-effect). In planning whey concentrating equipment, these costs should be studied.

The vapor-line preheater (62) provides an economical means of raising the temperature of the whey from storage temperature (40° F.) to separating temperature (90°). The steam required for this purpose comes from the second effect on the evaporator (72). Using a vapor-line preheater results in further savings as it reduces the amount of vapor needed to be condensed by the condenser in the evaporator, reducing the size of the cooling tower and related water handling equipment.

Cleaning Equipment

Much of the labor needed to operate a cheese plant is that required to clean equipment and utensils. All equipment and utensils that come in contact with cheese or ingredients used in cheese must be cleaned immediately after use. Proper cleaning methods are important not only for public health reasons, but also to control quality in the finished cheese, especially by combating bacteriophage contamination of the starter and the cheese milk.

Cleaning closed systems, such as storage tanks and HTST pasteurizing units, by circulating methods is a common practice in milk and ice cream plants. These same practices can be followed in cheese plants to reduce labor costs and to make the cleaning operations more efficient in use of chemicals, in removing soil, and in sanitizing the surfaces that come in contact with milk. Some equipment, however, such as cheese vats, is not adaptable to circulation cleaning and must be handwashed.

In closed circuits, such as the HTST units, the circulating pump connected with the unit can force the cleaning and sanitizing solutions through the entire system and back to the solution tank. But where the circuit cannot be put under pressure the entire distance, as in washing a milk truck tank or a storage tank, the CIP circulating pump delivers the cleaning or sanitizing solution to a spray ball system mounted at the top of the tank, which circulates the solution, and a separate pump returns the solution to the CIP unit for recirculation.

CLEANED-IN-PLACE (CIP) SYSTEM

Three CIP units (80, 81, 81A) are used in this plant. Two of them (81, 81A) have three-compartment tanks so that both acid and alkali solutions can be used. System 80 has two compartments and is used for cleaning the truck tanks; unit 81 is used for pipelines, weigh tanks, storage tanks, the HTST unit, and the 300-gallon bulk culture tank (20). Unit 81A is used in the whey department. For cleaning surfaces coming in contact with only cold milk, such as the milk tank trucks, ordinarily only the alkali wash solution is used. For cleaning surfaces coming in contact with hot milk, however, both acid and alkali solutions should be used. All the storage tanks have built-in spray balls that give sufficient hydraulic action to clean the soiled surfaces.

The CIP unit comes completely assembled. Individual program punchcards are used to give each item of equipment the optimum cleaning cycle. The unit is 41 inches wide, 61 inches long, and 74 inches high. Each stainless steel tank has a maximum working capacity of 165 gallons, and the flow of solutions to and from the unit is regulated by air-actuated valves. The CIP unit includes a temperature-control device, a level control, a recorder, air blowdown, and cleaning cycle unit with electropneumatic punchcard program selector located in the process control panel (82, 84, 85), for each type of cleaning required.

The automatic CIP units clean and sanitize the surfaces of milk processing equipment that come in contact with milk, without dismantling, by controlled circulation of cleaning and sterilizing solutions. This is performed by automatically regulating the temperature and elapsed time for each phase of the cleaning cycle. A CIP recorder-controlling instrument keeps a record of the cleaning procedure for review by management and health regulatory agencies. The time, temperature, and pressure of the cleaning, rinsing, and sterilizing solutions are recorded here. The CIP controls are shown on the process control panels (82, 84, 85).

Coupled with the recorder-controller is an electropneumatic punchcard program selector. This device automatically sets the elapsed time, circulating temperature, and proper valve sequencing for whatever item of equipment is to be cleaned. To clean a particular item, the proper punchcard is selected from the card file and inserted into the program selector. The program may be changed by making up a new punchcard. Once the program is established, there is no need for a variation unless some factors, such as the cleaning compounds, are changed.

Valve sequencing is necessary to insure proper cleaning of valve parts as well as branch lines. The program controller sets the sanitary line valves in the proper position for cleaning and also sequences the proper valves to clean the branch lines.

The "Off-On" pushbutton turns on the power to the control system, and the "Start" button initiates the program selected by the punchcard. The "Stop" button shuts off the program at any point, should the operator wish to do this; the program may again be picked up by the "Start" button. If the operator should desire to restart the program from the beginning, the "Reset" button is pushed, followed by the "Start" button. With a quick glance at the pilot lights, located just below the operating pushbuttons, the operator knows immediately which phase the CIP unit is in.

A CIP selector switch is provided in the control panel to direct the CIP solutions to the proper point for cleaning the equipment item selected. This switch also registers on the visual readout of control panel 82.

To clean the various tanks, a swing-elbow connection must be made at the CIP hook-up stations (81B-D), which connects the spray balls to the CIP solution lines. This connection is made by removing the manhole cover of the tank to obtain a key which unlocks the cap covering the solution line. This procedure insures that the tank is properly vented to prevent its collapse from vacuum during the final cold water rinse.

Pipelines are cleaned by making the necessary hose-jumper connections to complete circuits, followed by circulation of the solutions and valve sequencing by means of the automatic CIP units.

Items of equipment in the main plant that will not be cleaned by CIP methods are:

1. Positive displacement pumps
2. Slab curd conveyor
3. Cheese vats
4. Curd milling, salting, and hooping machine
5. Cheese presses
6 Sanitary skids for hoop storage
7. Clarifier *
8. Bulk culture vats located in the starter room
9. Whey clarifier *
10. Whey separator *

* Recently some machines have been placed on the market that the manufacturers claim can be cleaned by CIP methods successfully.

To initiate the cleaning cycle for any storage tank, tank truck, set of milk lines, or processing equipment, the punched card for the cleaning operation for the respective item is inserted into the card-reading unit, the CIP selector is set for the equipment to be cleaned, and the operation set into motion by pushing the proper button. A sample procedure for an open-circuit cleaning procedure for storage tanks follows:

Prerinse:

a. Rinse tank automatically filled.

b. Temperature control set initially approximately 100° F.

c. Spray rinse and discharge to drain until clean.

d. Return to rinse tank and circulated 5 minutes.

Alkali wash:

a. Solution tank automatically filled.

b. Alkali washing powder added to solution tank by operator.

c. Initial time period set approximately 40 minutes.

d. Temperature control set initially approximately 140° F.

e. Circulate at adjusted temperature and time period, discharging back to solution tank.

f. Cycle ends with all solution returned to solution tank.

Rinse:

a. Rinse tank full from last prerinse return.

b. Rinse, temperature same as prerinse, for 5 minutes.

c. Circulate water at tap temperature for 10 minutes and return to rinse tank.

Sanitize: (To be done just before using.)

a. Insert card for sanitizing program.

b. Sanitize chemical powder added to tank by operator.

c. Circulate cold for required period advised by sanitizer manufacturer, which is programed on card.

d. Discharge to drain.

The CIP procedure using three-tank unit for cleaning hot surfaces is as follows:

Prerinse:

a. Rinse tank automatically filled.

b. Temperature control set initially approximately 100° F.

c. Rinse through lines and discharge to drain until clear.

d. Return to rinse tank when clear; circulate 5 minutes.

Alkali wash:

a. Solution tank automatically filled.

b. Alkali wash powder added to solution tank by operator.

c. Initial time period set approximately 30 minutes.

d. Temperature control set initially approximately 165° F.

e. Circulate at adjusted temperature and time period, discharging back to solution tank.

f. Cycle ends with all solution returned to solution tank.

Rinse:

a. Rinse tank full from last prerinse return.

b. Rinse at 165° F. for 2 minutes maximum; discharge to drain.

Acid wash:

a. Solution tank automatically filled.

b. Acid cleaner added to solution tank by operator.

c. Initial time period set approximately 20 minutes.

d. Temperature control set initially approximately 165° F.

e. Circulate at adjusted temperature and time period, discharging back to solution tank.

Rinse:

a. Rinse tank full from last prerinse return.

b. Rinse same temperature as prerinse for 5 minutes; discharge to drain.

c. Circulate rinse water at tap temperature for 10 minutes; return to rinse tank.

Sanitize: (To be done just before using.)

a. Insert card for sanitizing program.

b. Sanitize chemical powder added to rinse tank by operator.

c. Circulate cold for required period advised by sanitizer manufacturer, which is programed on card.

d. Discharge to drain.

CLEANED-OUT-OF-PLACE (COP) SYSTEM

Some take-down sanitary pipes and certain pieces of equipment, such as positive displacement pumps, clarifiers, curd knives, strainers, dippers, and pails, need to be cleaned out of place. The machines are taken apart and rinsed free of milk remnants, and the various parts and other loose items of equipment are placed in small tanks (79) especially made for COP cleaning.

The stainless steel tank is 20 inches wide, 18 inches deep and 74½ inches long. It has a capacity of 100 gallons of washing solution. The heat-controlled flow circulation system assures thorough scrubbing of any shaped piece. A circulating pump is mounted beneath the tank. A two-way valve in the pump discharge line permits recirculation of cleaning or sanitizing solution or discharge to the floor. After the parts are rinsed with 100° F. water, cleaning and sanitizing solutions are recirculated through the tank in the same manner as the CIP system operates. The type and strength of the cleaner used will need to be varied according to the degree of soiling.

Auxiliary equipment needed with the COP tank includes a small parts basket, clarifier discs rack, sanitary fittings rack, clarifier truck, and a crane truck for hoisting heavy bowls from clarifier frame. The tanks and certain of the auxiliary items are mounted on casters so that they can be moved where needed.

MANUAL CLEANING AND SANITIZING

The exteriors of all large items of equipment must be kept free of soil. This is done by the operator while or after the equipment is used. Hosing with warm water usually suffices. Some large items of equipment must be handwashed, such as cheese vats and balance tanks.

CLEANING THE WHEY-HANDLING EQUIPMENT

CIP unit 81A, located in the whey-handling department, is used for cleaning the whey-receiving tanks, the evaporator, the heaters, the condensed whey plate cooler, the condensed whey storage tanks, the pipeline that brings the whey from the cheese vats to the whey handling department, and the whey cream storage tank. The positive displacement pumps, clarifier, and separators are cleaned out of place, though some of the newer clarifiers and separators can be cleaned in place, according to the manufacturer.

The methods used for cleaning these items are essentially the same as those used in the main plant using unit (81) with the controls located in the control panel (82).

Loading Out

The cheese is loaded out from an enclosed loading dock which is 10 feet deep and 110 feet long. The dock has two loading doors so that two trucks may be loaded at a time.

The cheese is put into the truck on the same pallets on which it is stored in the 40° F. storage room. The pallets are sized so that they can be placed in the delivery truck in two rows stacked two high. A forklift is used to load the trucks.

About 40 pallet loads of cheese are loaded out on an average day. Since the buyers provide their own trucks which differ considerably in capacity, the volume loaded out per truck varies from day to day. Generally, no more than three or four trucks are loaded in one day.

LABOR REQUIREMENTS

A total of 22 workers are needed to operate an automated plant of this size, excluding office workers. Each worker will work an 8-hour day, 5 days a week, with a 30-minute lunch period, except for the plant superintendent and engineer who will have 1-hour lunch periods.

Plant Workers Needed

The workers and their principal duties are as follows:

No.	*Worker*	*Principal duties*
1.	Superintendent	Supervises all plant operations, makes records, hires workers, assigns jobs.
2.	Engineer	Maintains all equipment in plant.
3.	Foreman	Assists superintendent and takes short relief assignments.
4.	Receiver	Receives milk, does cleaning and yard work.
5.	Cheesemaker	Takes care of cheese vats 1 and 6.
6.	Cheesemaker	Takes care of cheese vats 2 and 7.
7.	Cheesemaker	Takes care of cheese vats 3 and 8.
8.	Cheesemaker	Takes care of cheese vats 4 and 9.
9.	Cheesemaker	Takes care of cheese vat 5, 5 days per week, finishes vats 6, 7, 8, 5 days per week, and vat 9, 2 days per week.
10.	Assistant to cheesemaker	Inserts bandages in hoops.
11.	Assistant to cheesemaker	Hoops cheese and places on conveyor.
12.	Assistant to cheesemaker	Dehoops.
13.	Stacker	Stacks cheese for drying.
14.	Starter technician	Takes care of all starters 5 days per week.
15.	Laboratory technician	Works in laboratory.
16.	Laboratory technician	Works in laboratory.
17.	Storeroom clerk	Takes care of storeroom, receiving and shipping of merchandise; turns cheese in p.m.
18.	Whey plant operator	Separates whey and condenses whey.
19.	Whey plant worker	Separates, condenses, cools whey; does maintenance.
20.	Relief man	Relieves workers 5, 10, 12, 16, 17, one day each.
21.	Relief man	Relieves workers 6, 7, 11, 13, 18, one day each.
22.	Relief man	Relieves workers 3, 4, (2 days) 8, 9 (1 day).

In assigning relief workers, job assignments were rotated so that these workers would obtain broader experience. Rotating jobs also provides a method for training new workers for the various types of jobs in the plant.

Work Schedules

Work schedules for the specified plant employees are as follows:

Worker No. 1
(Superintendent):

Hours to be arranged.	General supervision of all operations and all workers. Hires workers and assigns them to their duties. Makes necessary reports.

Worker No. 2
(Maintenance engineer):

2 days per week, 7:00 a.m. – 3:30 p.m. 3 days per week 12 m. – 8:30 p.m.	Care of all automatic machines and their controls, keeping them oiled, adjusted, and in good repair.

Worker No. 3
(Foreman):

7:00 a.m. – 3:30 p.m.

7:00	Sanitize equipment for receiving milk.
8:00	Start pasteurizer.
8:05	Pump starter into milk line leading to cheese vat 1.
8:55	Prepare rennet for vat 1.

Worker No. 3—Continued:

9:00	Switch valve on milk line from vat 1 to vat 2. Add rennet to vat 1, agitate milk, remove paddles.
9:05	Pump starter into milk line leading to vat 2.
9:30	Assist cheesemaker in cutting curd in vat 1.
9:55	Prepare rennet for vat 2.
10:00	Switch valve on milk line from vat 2 to vat 3. Add rennet to vat 2, agitate milk, remove paddles.
10:05	Pump starter into milk line leading to vat 3.
10:30	Assist cheesemaker in cutting curd in vat 2.
10:55	Prepare rennet for vat 3.
11:00	Switch valve on milk line from vat 3 to vat 4. Add rennet to vat 3, agitate milk, remove paddles.
11:05	Pump starter into milk line leading to vat 4.
11:05	Lunch.
11:30	Assist cheesemaker in cutting curd in vat 3.
11:30	Relieve receiving man for lunch.
11:55	Prepare rennet for vat 4.
12:00 m.	Switch valve on milk line from vat 4 to vat 5.
12:05	Pump starter into milk line leading to vat 5.
12:30	Assist cheesemaker in cutting curd in vat 4.
12:55	Prepare rennet for vat 5.
1:00	Switch valve on milk line leading from vat 5 to vat 6. Add rennet to vat 5, agitate milk, remove paddles.
1:05	Pump starter into milk line leading to vat 6.
1:30	Assist cheesemaker in cutting curd in vat 5.
1:35	Place bandages in hoops for vat 1.
1:55	Prepare rennet for vat 6.
2:00	Switch valve on milk line from vat 6 to vat 7. Add rennet to vat 6, agitate milk, remove paddles.
2:05	Pump starter into milk line leading to vat 7.
2:30	Assist cheesemaker in cutting curd in vat 6.
2:35	Place bandages in hoops for vat 2.
2:55	Prepare rennet for vat 7.
3:00	Switch valve in milk line from vat 7 to vat 8. Add rennet to vat 7, agitate milk, remove paddles.
3:05	Pump starter into milk line leading to vat 8.

Worker No. 4 (Receiver):
7:15 a.m. – 3:45 p.m.

7:15	Check equipment for receiving milk.
7:30	Start receiving milk and washing bulk milk delivery trucks.
11:30	Lunch.
12:00 m.	Receive milk.
2:00	Clean equipment and take care of premises.

Worker No. 5 (Cheesemaker):
9:30 a.m. – 6:00 p.m.

9:30	Operate vat 1 from curd cutting to vat washing.
2:00	Lunch.
2:30	Operate vat 6 from curd cutting to 4-high stacking.

Worker No. 6 (Cheesemaker):
10:30 a.m. – 7:00 p.m.

10:30	Operate vat 2 from curd cutting to vat washing.
3:00	Lunch.
3:30	Operate vat 7 from curd cutting to 4-high stacking.

Worker No. 7 (Cheesemaker):
11:30 a.m. – 8:00 p.m.

11:30	Operate vat 3 from curd cutting to vat washing.

Worker No. 7—Continued:

3:55	Prepare rennet for vat 8.
4:00	Switch valve from vat 8 to vat 9. Add rennet to vat 8, agitate, remove paddles.
4:05	Lunch.
4:35	Operate vat 8 from curd cutting to 4-high stacking.

Worker No. 8
(Cheesemaker):
12:30 to 9:00 p.m.

12:30	Operate vat 4 from curd cutting to vat washing.
4:55	Prepare rennet for vat 9.
5:00	Shut off pasteurizer for vat 9, add rennet, agitate milk, remove paddles.
5:05	Lunch.
5:35	Operate vat 9 from curd cutting to vat washing. On 8-vat days (Wed., Thurs., Fri., Sat.) wash walls of cheese room.

Worker No. 9
(Cheesemaker):
1:30 – 10:00 p.m.

1:30	Operate vat 5 from curd cutting to vat washing.
5:50	Start CIP.
6:00	Lunch.
6:30	Operate vat 6 from final 4-high turn to vat washing.
7:00	Operate vat 7 from first 4-high turn to vat washing.
8:00	Operate vat 8 from first 4-high turn to vat washing.
9:00	Operate vat 9 from first 4-high turn to vat washing.

Worker No. 10
(Assistant to cheesemaker):
3:45 p.m. – 12:15 a.m.

3:45	Put bandages in hoops for vat 3.
4:15	Move hoops from overhead conveyor to press of vat 3.
4:30	Dress bandages on hoops at press of vat 2.
4:45	Put bandages in hoops for vat 4.
5:15	Move hoops from overhead conveyor to press of vat 4.
5:30	Dress bandages on hoops at press of vat 3.
5:45	Put bandages in hoops for vat 5.
6:15	Move hoops from overhead conveyor to press of vat 5.
6:30	Dress bandages on hoops at press of vat 4.
6:45	Put bandages in hoops for vat 6.
7:15	Lunch.
7:45	Put bandages in hoops for vat 7.
8:15	Move hoops from overhead conveyor to press of vat 7.
8:30	Dress bandages on hoops at press of vat 6.
8:45	Put bandages in hoops for vat 8.
9:15	Move hoops from overhead conveyor to press of vat 8.
9:30	Dress bandages on hoops at press of vat 7.
9:45	Put bandages in hoops for vat 9.
10:15	Move hoops from overhead conveyor to press of vat 9 on Wed., Thurs., Fri., and Sat.
10:30	Dress bandages on hoops at press of vat 8.
10:45	Wash milling, salting, and hooping machine.

Worker No. 11
(Assistant to cheesemaker):
3 days per week;
1:00 – 9:30 p.m.
2 days per week;
1:45 – 10:15 p.m.

1:00	Prepare and sanitize milling, salting, and hooping machine.
1:10	Fill salt hopper on machine.
1:15	Move hoops of vat 1 from day before from press to overhead conveyor.
1:45	Hoop curd in vat 1 and place on overhead conveyor.

Worker No. 11—Continued:

2:15	Move hoops from overhead conveyor to press of vat 1 and move hoops of vat 2 from day before from press to overhead conveyor.
2:45	Hoop curd in vat 2 and place on overhead conveyor.
3:15	Move filled hoops from conveyor to press of vat 2 and move hoops of vat 3 from day before from press to overhead conveyor.
3:45	Hoop curd in vat 3 and place on overhead conveyor.
4:15	Move hoops of vat 4 from day before from press to overhead conveyor.
4:30	Assist cheesemaker cut curd in vat 8.
4:35	Refill salt hopper.
4:45	Hoop curd in vat 4 and place on overhead conveyor.
5:15	Lunch.
5:45	Hoop curd in vat 5 and place on overhead conveyor.
6:00	Check CIP and COP.
6:20	Move hoops of vat 6 from day before from press to overhead conveyor.
6:45	Hoop curd in vat 6 and place on overhead conveyor.
7:15	Move filled hoops from overhead conveyor of press of vat 6 (worker 10 eats lunch).
7:30	Dress bandages on hoops at press of vat 5 (worker 10 eats lunch).
7:45	Hoop curd in vat 7 and place on overhead conveyor.
8:15	Check CIP and COP.
8:20	Move hoops of vats 8 and 9 from day before from press to overhead conveyor.
8:45	Hoop curd in vat 8 and place on overhead conveyor.
9:15	Finish CIP and clean COP. Job ends at 9:30 p.m. 3 days each week.

Worker No. 11—Continued:

9:30	Refill salt hopper.
9:45	Hoop curd in vat 9, place on overhead conveyor.

Worker No. 12
(Assistant to cheesemaker):

1:00 – 9:30 p.m.

1:00	Fill hoop washer and prepare area for dehooping and washing.
1:15	Dehoop, wash hoops from vat 1 of day before.
1:45	Paraffin vat of daisies.
2:15	Dehoop, wash hoops of vat 2 from day before.
2:45	Paraffin vat of daisies.
3:15	Dehoop, wash hoops from vat 3 of day before.
3:45	Paraffin vat of twins.
4:15	Dehoop, wash hoops from vat 4 of day before.
4:45	Paraffin vat of twins.
5:15	Dehoop, wash hoops from vat 5 of day before.
5:45	Lunch.
6:15	Dehoop, wash hoops of vat 6 from day before.
6:45	Paraffin vat of twins except on Mon., Tues., Fri., and Sat. (On these days, clean dry storage room and drying racks.)
7:15	Dehoop, wash hoops of vat 7 from day before.
7:45	Paraffin vat of cheddars.
8:15	Dehoop, wash hoops of vat 8 from day before.
8:45	Paraffin vat of cheddars.
9:15	Dehoop, wash hoops of vat 9 from day before.

Worker No. 13
(Stacker):

2:00 – 10:30 p.m.

2:00	Remove hoops from washer (vat 2).
2:45	Stack cheese on racks (vats 1 and 2).
3:00	Help No. 12 paraffin vat of daisies.

Worker No. 13—Continued:

3:15	Remove hoops from washer (vat 3).
3:45	Stack cheese on racks (vat 3).
4:00	Help No. 12 paraffin vat of twins.
4:15	Remove hoops from washer (vat 4).
4:45	Stack cheese on racks (vat 4).
5:00	Help No. 12 paraffin vat of twins.
5:15	Remove hoops from washer (vat 5).
5:45	Lunch.
6:15	Remove hoops from washer (vat 6).
6:45	Move 2 vats (5 and 6) of blocks to cooler.
7:00	Help No. 12 paraffin vat of twins. (On Mon., Tues., Fri., and Sat., clean walls of cheese cooler.)
7:15	Remove hoops from washer (vat 7).
7:45	Stack cheese on racks (vat 7).
8:00	Help No. 12 paraffin vat of cheddars.
8:15	Remove hoops from washer (vat 8).
8:45	Stack cheese on racks (vat 8).
9:00	Help No. 12 paraffin vat of cheddars.
9:15	Remove hoops from washer (vat 9*). Dehoop remainder of vat 9.
9:45	Stack cheese on racks (vat 9*). *On 8-vat days, wash one wall of hoop storage room each day instead of work shown on vat 9.
10:00	Drain hoop washer, wash floor.

Worker No. 14
(Starter technician):

Hours to be arranged.	On 6th day checks batch of culture set on 5th day. Has complete charge of the starter program.

Workers No. 15 and 16
(Laboratory technicians):

Hours to be arranged. Work of each technician complements that of the other; hours are arranged so one is in laboratory each of 6 working days.	Duties outlined in section on "How the Plant Operates," which describes the functions of the laboratory.

Worker No. 17
(Storeroom clerk):

Hours to be arranged.	Loads out cheese. Checks in freight. Supplies cheeseboxes and paraffin to dehooping and paraffining rooms. Supplies 10-pound paper boxes to block-wrapping room. Furnishes haulers with patron supplies (orders made up the day before). Supplies starter room with powder needs. Weighs out chemicals for CIP and COP systems. Prepares shipping orders and receiving records. Supplies salt to curd-milling machine. Turns round cheeses on racks in afternoons. Dresses bandages on vat 1. Moves hoops of vat 5 from day before from press to overhead conveyor. Moves hoops of vat 7 from day before from press to overhead conveyor.

Worker No. 18
(Whey-plant operator):

11:00 a.m. – 7:00 p.m.
: Set up whey clarifier and separator.
Assembles open fittings and sanitizes separator, evaporator, plate cooler and tanks.
Starts separator, evaporator, and plate cooler; checks boiler and compressors.
Checks solids, draws off condensed whey, cools condensed whey, and pumps into storage tanks.
Checks acidity of raw whey every hour.
Checks automatic solids test reading on condensed whey every half hour.
Checks temperature of heated whey, evaporator, vapors, cooled whey, and cooled whey cream every half hour.
Checks whey cream thickness.
Checks ammonia pressures.
Checks boiler operation, water level, and pressure.
Checks all bearings periodically for malfunction.
Checks all equipment maintenance possible while in operation.
Pumps condensed whey to tank truck.
Pumps whey cream to tank truck.
CIP cleans condensed whey storage tanks and whey cream tanks.
Eats lunch while equipment is under normal operation.

Worker No. 19
(Whey-plant worker):

7:00 p.m. – 3:30 a.m.
: Finishes whey evaporation (on 9-vat days).
Pumps balance of condensed whey from evaporator through plate cooler and into condensed whey storage tanks.
Bypasses clarifier and separator[3] and circulation cleans whey storage tanks, heaters, evaporator, plate cooler, and sanitary lines.
COP cleans clarifier and separator.
Adjusts machinery, replaces worn parts.
Checks boiler blowdown, boiler cleaning, and burner adjustment.
Adds ammonia to compressors.
Scrubs floors daily and walls and ceiling as needed in whey-handling area, refrigerator room, boiler room, and shop.

Workers No. 20 – 22
(Relief workers):

Hours to be arranged.
: To maintain a 40-hour work schedule for this plant, 3 relief workers are needed. Their hours will be as required to meet the schedule of the regular workers given above.

To show the sequence of operations in making a batch of cheese and to better explain each worker's part in the cheesemaking process, the following timetable is given. The other vats of cheese follow the same schedule at 1-hour intervals until all eight (or nine) batches are completed.

A.M.	
8:00	Start filling vat; begin adding starter.
8:10	Finish adding starter.
9:00	Vat filled; rennet added.
9:30	Curd cut.
9:40	Paddles detached; agitators started.
9:50	Steam on in jacket.
10:30	Steam off in jacket.

[3] Unless self-cleaning clarifier and separator are used.

11:20	Draw half of whey; run acidity test on whey.
11:25	Stop agitators; start ditching (making trough).
12:00	Draw remainder of whey; run acidity test on whey.
P.M.	
12:05	Cut curd into blocks.
12:10	Turn blocks.
12:15	Turn blocks.
12:20	Turn blocks.
12:25	Turn blocks.
12:30	Cut blocks in two parts.
12:35	Pile blocks 2 high.
12:40	Turn blocks.
12:45	Pile blocks 3 high.
12:50	Turn blocks.
1:00	Pile blocks 4 high.
1:10	Turn blocks.
1:20	Turn blocks.
1:30	Turn blocks.
1:35	Run acidity test on whey.
1:40	Pile curd blocks on belt conveyor. Salt added to milling machine.
1:45	Start bandaging hoops; start milling machine and hoop filling.
1:50	Wash vat.
1:55	Finish bandaging hoops.
2:15	Finish milling, salting, and hooping; put filled hoops on presses.
2:30	Apply pressure to hoops.
3:30	Adjust bandages.
3:45	Apply pressure to hoops.
Following day	
1:15 – 1:45	Remove hoops from press and place on overhead conveyor to the dehooper.

COSTS AND POSSIBLE BENEFITS OF LABOR-SAVING DEVICES

The equipment required for the automated cheddar cheese plant to minimize labor requirements and estimated costs of the items based on 1968-69 prices are as follows:

	Dollars
Weighing tank load cell system	8,000
Three CIP units and CIP pipe	24,000
Automatic control instruments	25,000
Milling and salting machine	52,000
Conveyor system for carrying hoops	8,000
Automatic hoop washer and conveyor	4,000
Automatic block cutting, wrapping, boxing	15,000
Mechanical agitators for cheese vats	15,000
Load cells for weighing tanks	5,000
Tank gages	9,000
Control panels with switches	15,000
Additional sanitary pipeline and air-operated valves	15,000
Controls for boilers and refrigeration units	5,000
Subtotal	200,000

Additional refrigeration machinery, and air temperature and humidity controls in starter room, drying room, and plant follow:

	Dollars
Two 100-ton compressors	20,000
One 198-ton chilled water unit	10,000
One 30-ton air conditioner	3,200
Two 15-ton air conditioners	4,600
Two 45-ton air conditioners	8,800
One 22½-ton air conditioner	2,300
One 12-ton air conditioner with high frequency filters	2,400
Pumps and piping	10,000
Subtotal	62,000
Total	262,000

Thus, the estimated cost of the equipment would be $262,000 greater than that for the nonautomated plant.

The automated plant could operate with an estimated 21 fewer workers than a properly arranged and operated nonautomated one handling a similar volume. Based on an assumed costs of $6,500 annually per worker (salary plus fringe benefits), the annual savings in labor would be $136,500 for an automated plant. If 20 percent is allowed annually for ownership and operating costs (depreciation, interest, insurance, taxes, maintenance, and power), the costs would amount to $52,400 and an annual saving of $84,100 would result.

Production per man-hour of labor should be higher in the automated than in the nonautomated plant. The production on a peak day in the automated plant would be about 88 pounds of cheese per man-hour compared with 45 pounds per man-hour in a nonautomated plant.

Machine-controlled operations should reduce in-plant production losses and provide a more uniform cheese than that obtained in a nonautomated plant using conventional equipment. No data, however, are available for the savings that would be realized from these items.

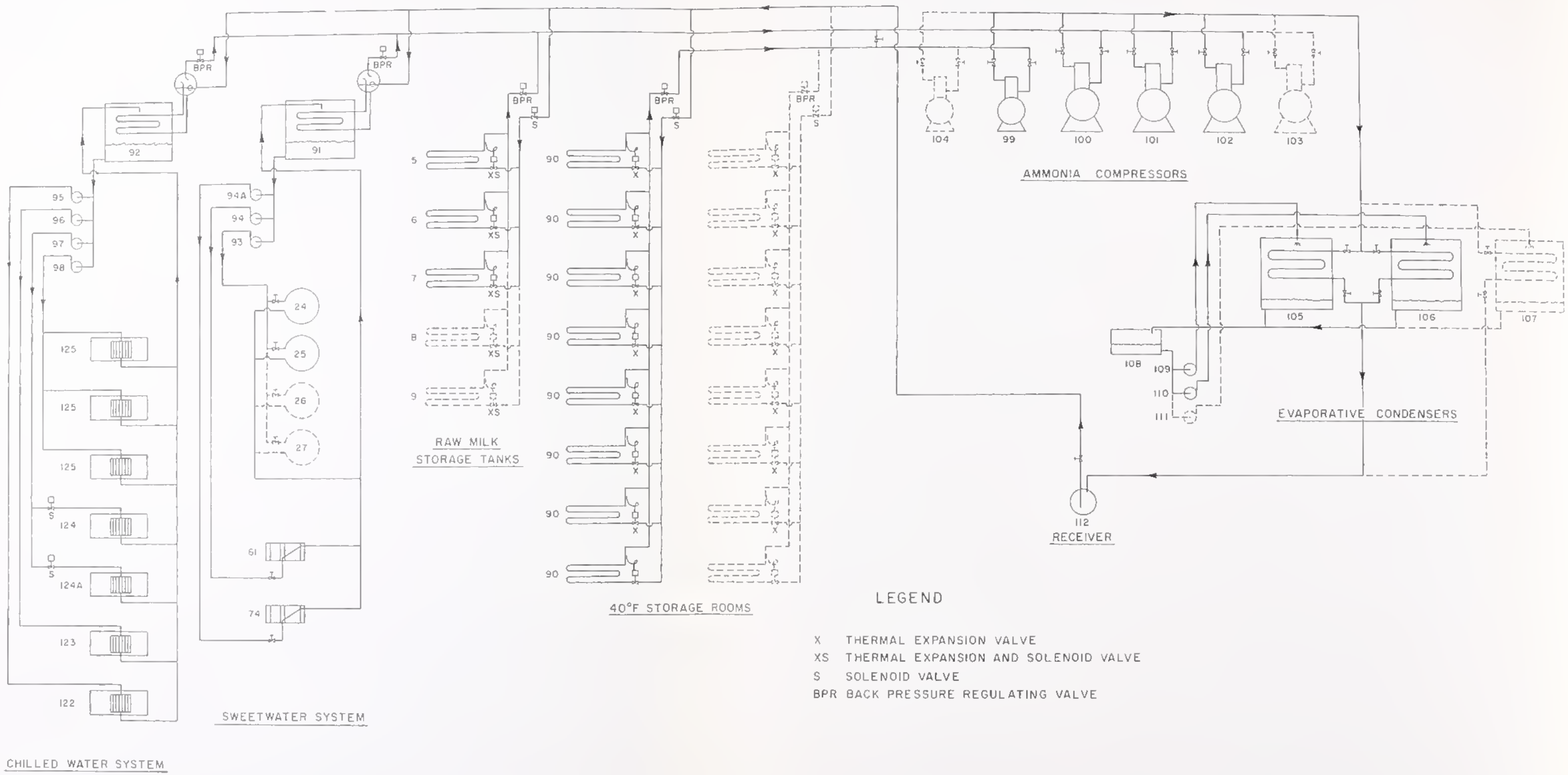

FIGURE 9.—A suggested refrigeration system for an automatedcheddar cheese plant handling 800,000 pounds of milk weekly.

APPENDIX: REFRIGERATION, HEATING, VENTILATING, AND AIR CONDITIONING

Refrigeration System

The refrigeration system (fig. 9) for the plant should be adequate to cool milk and whey products, to maintain the required room temperature and humidity in the drying room and 40° F. storage room, and to handle the air-conditioning load. All of the refrigeration is supplied by an ammonia refrigeration system, except that for the drying room. This room is on a separate Freon condensing unit so that the humidity here can be closely controlled.

The refrigeration calculations are based partly on data contained in the "Mechanical Engineers' Handbook," "Heating, Ventilating, and Air Conditioning Guide," and "Refrigeration Engineering Application Data."[4]

Starter in 300-gallon vats (24, 25), whey passing through a plate heat exchanger (61), and concentrated whey passing through a plate heat exchanger (74) are cooled by 34° F. sweet water. The sweet water is recirculated through sweetwater cooling unit (91). The air-conditioning units (122, 123, 124, 124A, 125) are refrigerated by recirculating chilled water at 38°. This water is recirculated through chilled water cooling unit (92). These two cooling units are identical except that one is sized to maintain a temperature of 34° and the other 38°. To distinguish between the two units, one is referred to as a sweetwater cooling unit (34° water) and the other a chilled water cooling unit (38° water).

These cooling units consist of corrugated stainless steel plates over which water flows from a distributing trough on top to a collecting tank on the bottom. The water level is maintained by a float control in the collecting tank. Ammonia is evaporated inside the corrugated sections, thus cooling the water. The ammonia flow is controlled by a gravity-type flooded ammonia control with ammonia float valve to control the incoming liquid and a back pressure regulating valve to control the ammonia temperature within the corrugated sections. Pumps (93, 94, 94A, 95, 96, 97, 98) are used to circulate the water through the equipment.

The raw milk storage tanks (5, 6, 7) are equipped with cold-wall sections which consist of a corrugated stainless steel sheet welded to the outside of the inner jacket on the bottom part of the tank. Liquid ammonia is admitted to these coils by combination solenoid-thermostatic expansion valves, which will maintain the milk at 38° F. The temperature of the ammonia in the refrigerated section is controlled by an ammonia back pressure regulating valve. The flow of ammonia may be turned off by a push-button in control panel (82). The refrigeration load of these tanks is small in comparison to other loads and occurs principally when other loads are off. Therefore, it is not included in the calculations which determine the size of the ammonia compressor equipment.

The cold storage room is maintained at the desired temperature (40° F.) by eight cooling units (90) suspended from the ceiling. Each unit has coils in which ammonia evaporates, cooling them. Air is blown over these coils by a fan in the unit to cool the room. The flow of ammonia through the coils is controlled by a thermostatic expansion valve, and the temperature of the ammonia in the coil is controlled by an ammonia back pressure regulating valve.

The factors used in determining the sizes of equipment suggested for the plant are described below. The refrigeration requirements presented here are offered as a guide only, since many conditions, such as temperature differences, types of building materials used, and plant location, affect the requirements of a particular plant. Operators planning to build new plants or remodel present facilities should consult local refrigeration engineers for their specific requirements.

SWEETWATER COOLING UNIT (91) LOADS

These loads would be based on the plant's peak operating capacity. This capacity occurs

[4] MARKS, LIONEL S. MECHANICAL ENGINEERS' HANDBOOK, 4th ed., illus. 1941; AMERICAN SOCIETY OF HEATING AND AIR CONDITIONING ENGINEERS. HEATING, VENTILATING AND AIR CONDITIONING GUIDE. 1947; SEGAL, S. CHARLES. REFRIGERATION LOAD CALCULATIONS — II. TEMPERATURES BELOW 32° F. REFRIG. ENGIN. APPLIC. DATA 12. Refrig. Engin. Vol. 39, No. 4, Sec. 2. April 1940.

when starter, whey, and whey concentrate are being cooled at the same time. The starter is cooled from 70° to 40° F. in 1 hour. Preliminary cooling in the plate heat exchangers is done with 68° well water. The formula for hourly B.t.u. (British thermal units) requirements is:

B.t.u. per hr. = Weight of product per hr. × Temperature change × Specific heat

Equipment No.	Product	Rate of cooling per hr.	Temperature change	Specific heat	B.t.u. per hr.
		Lb.	° F.		
24, 25	Starter	5,160	70–40	1.0	154,800
61	Whey	20,000	76–40	1.0	720,000
74	Conc. whey (40% TS)	3,000	90–40	.9	135,000
Total					1,009,800
10 percent for line and pumping loss					100,980
Total required					1,110,780

The compressor capacity required would be:

$$\frac{1,110,780}{12,000} = 92.5 \text{ tons.}$$

CHILLED WATER COOLING UNIT (92) LOADS

The chilled refrigeration loads in tons for the seven air-conditioning units (122-125) are listed below. The loads are as recommended by equipment manufacturers for the size of room and type of equipment in the room.

Unit number	Rooms where used	Volume of area	Air circulated	Chilled water refrigeration load
		Cu. ft.	*C.f.m.*	*Tons*
122	Laboratories, offices, and office toilets	29,770	7,500	30
123	Culture, mother culture	12,096	4,000	12
124	Paraffining, hoop wash	35,104	10,000	30
124A	Restrooms, lunchrooms, locker rooms	24,784	5,000	15
125 (3)	Cheese processing, pasteurizing	210,560	60,000	90
Total				177

40° F. ROOM COOLING UNIT (90) LOADS

The factors which determine the refrigeration requirements of the cold storage room are: (a) Heat gain through walls, ceiling, and floor, (b) heat gain through air changes in the coldroom (c) heat gain from electrical energy, and (d) heat gain from cheese held in the room. A heat gain would also be incurred from workers and forklift trucks which enter the room; however, for the proposed plant this would be only one or two people at a time, depending on the load-in or load-out situation at the time. Thus, the heat gain from this source would be comparatively small and is included in the suggested safety factor for the room. In these calculations, the peak average hourly load for all factors is computed with the exception of the heat gain from the cheese entering and being held in the room. The cheese will not give up all its heat the first hour; therefore, the average for a 24-hour period is used.

(a) Heat gain through walls, ceiling, and floor is calculated by the formula shown below. The calculations are based on a coldroom temperature of 40° F. and outside temperature of 95° F. An average overall coefficient of heat transmission for walls, floor, and ceiling of 0.0756 B.t.u. per hour per square foot per degree F. temperature difference is suggested. This is equivalent to a wall section of 8 inches of brick and 4 inches of insulation. The coldroom for the suggested plant would have a surface area of:

		Sq. Ft.
Walls	= 42×17×2+112×17×2 =	5,236
Ceiling	= 112×42 =	4,704
Floor	= 112×42 =	4,704
Total surface	=	14 644

Heat gain through walls, floor, and ceiling (B.t.u. per hour) = Surface area (square feet) × 0.0756 (B.t.u. per hour per square feet) × Temperature change (°F.)

14,644 × 0.0756 × 55 = 60,890 B.t.u. per hour.

(b) Heat gain from air changes is calculated by the following formula. It is estimated that a room of this type would have one air change every 2 hours, or 0.5 change per hour. This would occur principally when loading in or out of the room.

Heat gain from air changes (B.t.u. per hour) = Volume of room (cubic feet) × 2.53 (B.t.u. per hour per cu. ft.) × Number of air changes per hour

40×16×110×2.53×0.5=89,056 B.t.u. per hour.

(c) Heat gain from electrical energy is from electrical motors and lights. It is assumed that 4 horsepowers (hp.) are used on the eight cooling units. For this calculation, 1 hp. equals 3,700 B.t.u. per hour.

Heat gain from motors (B.t.u. per hour) = Motor horsepower × 3,700
= 4 × 3,700 = 14,800 B.t.u. per hour

It is assumed that 1,400 watts of electricity are used for lights; 1 watt-hour equals 3.42 B.t.u. per hour.

Heat gain from lights (B.t.u. per hour) = Number of watts × 3.42
= 1,400 × 3.42 = 4,788 B.t.u. per hour

Total heat gain from electrical energy = 19,588 B.t.u. per hour.

(d) Heat gained from product entering the room is determined from the maximum amount of cheese entering, or 17,366 pounds per day. Eighty percent of this comes from the drying room, and 20 percent is in prints, going directly to the 40° F. cold storage room from wrapping and boxing. To determine the refrigeration required, it is estimated that the average blend temperature of the cheese, packages, and pallets from the drying room is 60° F., and that this temperature coupled with the estimated specific heat factor results in an accurate estimate of the heat gain due to cheese entering the room. The blend temperature of the prints is estimated to be 80° F. The formula for determining the heat gain from products entering the room is:

Heat gain from cheese (B.t.u. per hr.)

$$= \frac{\text{Weight of cheese} \times \text{temp. change} \times \text{spec. heat}}{24 \text{ hours}}$$

$$= \frac{17{,}366 \times 20 \times 0.8 \times 0.6}{24} + \frac{17{,}366 \times 40 \times 0.2 \times 0.6}{24}$$

$$= 6{,}946 + 3{,}473 = 10{,}419 \text{ B.t.u. per hour.}$$

The following is a summary of heat gains in the cold storage room:

	B.t.u.
Walls, ceiling, floor	60,890
Air changes	89,056
Electrical energy	19,588
Cheese entering room	10,419
Total	179,953
10 percent allowance	17,995
Total requirements	197,948

Since the room cooling units (90) are to operate only 16 hours per day to provide 8 hours for automatic defrosting, the load of 197,948 B.t.u. must be removed from the room in two-thirds of an hour. Therefore, the cooling unit must remove 197,948 × 3 ÷ 2, or 296,922 B.t.u. per hour.

The total refrigeration load would be:

$$\frac{296{,}922}{12{,}000} = 24.7 \text{ tons.}$$

The eight cooling units (90) suggested have a capacity of 3.1 tons each, or a total of 24.8 tons.

The total refrigeration requirements are:

	Tons
Sweetwater cooling unit (91)	92.5
Chilled water cooling unit (92)	177.0
40° F. cold storage room	24.7
Total	294.2

To handle the refrigeration load, three 100-ton (100, 101, 102) and one 25-ton (99) ammonia compressors are suggested. The 100-ton compressors would operate at 40-pounds suction pressure and 185-pounds condensing pressure and would require 100-hp. electric motors. The 25-ton compressor would operate at 35-pounds suction pressure and 185-pounds condensing pressure and would require a 30-hp. electric motor.

The 25-ton compressor (99) is connected to the 40° F. storage room. It will start and stop automatically by a room thermostat, set to turn on at 40° and off at 38°. The thermostat will also shut off the supply of ammonia to the coils. The air circulation fans continue to run, thus automatically defrosting the coils by circulating room air over them. The suction line from the cooling units (90) to the 25-ton compressor is cross connected to the suction line from the chilled water and sweetwater units so that the other ammonia compressors may be used on the 40° F. room should the 25-ton compressor be shut down for repairs.

The three 100-ton compressors are the multicylinder type with 75- and 50-percent capacity controls. Thus, the three compressors provide a variable capacity of 50 to 300 tons at 25-ton increments. This capacity control is automatic by a pressure switch, which will maintain the suction pressure in a range of 35 to 40 pounds. As a load increases in an air-conditioning unit or any of the sweetwater refrigerated machinery, or on a cold-wall tank, the suction pressure will rise. This rise is sensed by the pressure switch, which adjusts the capacity controls to suit the condition. Except for turning the compressors on, the operation is fully automatic.

During the winter only one 100-ton compressor would be used. During periods of moderately warm weather two 100-ton compressors are required, and for hot weather all three 100-ton compressors would be on the line. The number of compressors used may also vary with the time of day, since at night in hot weather only one unit would be required.

To condense the ammonia, two 165-ton evaporative condensers (105, 106) are suggested. They are located outside the refrigeration room on concrete piers high enough that the liquid ammonia will drain by gravity to the 24-inch by 16-foot receiver (112). Since many cheese plants are located in areas which have severe cold weather in winter, the water from the sump pan on the evaporative condensers can be drained by gravity to the sump tank (108). Draining this water prevents the pumps and water from freezing, since they are located just inside the refrigeration room. During seasons of rapid change in temperature, this is advantageous, as the condensers can run dry at night when it is cold and the water pumps will start automatically during the day when the outside temperature rises. The pumps and piping never freeze, since when they are off all water drains to the sump tank.

The condensing pressure is controlled by pressure switches which start the fan and pump motors on a pressure rise. The first evaporative condenser fan would turn on at 150 p.s.i. (pounds per square inch) and off at 135 p.s.i. The second evaporative condenser would turn on at 155 p.s.i. and off at 140 p.s.i. The pumps on the first and second evaporative condensers would be set to turn on at 160 and 165 p.s.i., respectively, and off at 145 and 150 p.s.i. Thus, under low loading conditions, or cold outside air, the units would run dry.

DRYING ROOM AIR-CONDITIONING UNIT (131)

This unit differs from the other air-conditioning units in that it has a reheat coil; that is, the air first passes through a heating coil, then a cooling coil, followed by a second heating coil and a steam injection humidifying unit. A reheat coil is required because the humidity must be controlled within a very narrow range. The unit uses 15 percent makeup air all seasons of the year and is designed to maintain a temperature of 55° F. and a relative humidity of 70 percent at all times. The cooling coil is refrigerated by a 15-ton Freon condensing unit (128) located in the refrigeration room. This unit is controlled automatically by a humidistat and thermostat located in the drying room.

In winter, outside air, which is 10° F. and 80-percent relative humidity, when heated to 55° without the addition of moisture, would have a relative humidity of approximately 12 percent. Thus, under these conditons, heating is performed partly by the first heating coil, with final heating from the humidifying steam injection unit to result in the discharge of air at 55° and 70-percent relative humidity. In summer, outside air at 95° F. and 50-percent relative humidity, when cooled to approximately 74°, is saturated with moisture; that is, it has a relative humidity of 100 percent. Under these conditions, further cooling from 74° F. condenses moisture out of the air. To discharge air from the air-conditioning unit at 55° and 70-percent relative humidity, the air should be cooled to approximately 45° to condense sufficient moisture so that upon reheating to 55° the relative humidity will be 70 percent. Thus, in winter the first heating coil and humidifier are used; in summer the cooling coil and reheat coil are used. The above temperature and humidity conditions are for outside or makeup air and are, of course, tempered by the use of 85-percent recirculated air.

The use of this air-conditioning unit (131) permits maintaining constant temperature and humidity conditions in the drying room at all times.

Heating System

A heating system is required to provide steam for processing milk, cheese, and whey, as well as for heating water for cleaning equipment, and for heating the building. A heating system should be adequate to handle the peak requirements. These requirements depend to some extent on the climate of the area in which the plant is located. Thus, heating data provided herein are offered as a guide only. Operators of cheese plants planning to build new plants, or remodel their present facilities, should contact local heating engineers regarding their heating requirements.

The basic formula for determination of the B.t.u. requirements for heating milk products is:

$$\text{B.t.u. per hr.} = \text{Weight of product per hr.} \times \text{Temperature change} \times \text{Specific heat}$$

Tabulated below are the B.t.u. requirements for heating the various milk products handled in this plant, based on this formula. The whey vaporline preheater (62) receives its heat from the double-effect recompression evaporator (72) and is therefore not included. The B.t.u. requirements for operating the double-effect recompression evaporator are those recommended by manufacturers of this type of equipment. The culture vats (24, 25) heat through the temperature range indicated in 45 minutes; therefore, the B.t.u. requirements are adjusted to include this. The cheese vats (29–37) are heated through their range in 35 minutes consecutively; therefore, only one vat is included. The contents of the cheese vat include, in addition to the milk, 10 gallons of water (rennet addition) plus 1.00 percent starter.

Equipment number	Product	Amount of product per hour	Temperature change	Specific heat [1]	B.t.u. per hour
		Lb.	*° F.*		
13	Milk	20,000	109.5–161.5	1.0	1,040,000
29	Milk	20,241	87–104	1.0	344,097
24, 25	Milk	5,160	70–190	1.0	619,200
71	Whey	20,000	110–195	1.0	1,700,000
72	Whey conc.	17,000	—	—	[2] 5,900,000
127	Water	25,000	60–120	1.0	1,500,000
Total B.t.u. per hour required					11,103,297

[1] The actual specific heat of milk products is less than 1.0, but for simplicity, a value of 1.0 is used in these calculations.

[2] B.t.u. per hour requirements based on recommendation of manufacturer.

The estimated requirement for heating the building is based on 10 B.t.u. per hour per cubic foot. All areas of the building would be heated except the hallway, which is a principal exhaust area; the boiler room and whey-processing area, which are heated by radiation and motor heat; and refrigerated storage areas.

The areas to be heated follow:

	Cu. ft.
Laboratories, offices, office restrooms	29,770
Paraffining and hoop-washing room	35,104
Restrooms, lunchroom, and lockers	24,784
Cheese processing, pasteurizing room	210,560
Dry storage, cheese storage room	25,600
Repair shop	8,000
Whey storage	6,144
Receiving shelter	25,600
Total area	365,562
B.t.u. required (area × 10) =	3,655,620

The computed requirements for heating the products and the plant are 14,758,917 B.t.u. When 10 percent is added for line and radiation losses, the maximum hourly B.t.u. requirement is 16,234,808.

One boiler horsepower is equivalent to the heat required to evaporate 34.5 pounds of water in 1 hour, or a heat requirement of 33,524 B.t.u. per hour. Since makeup water is below 212° F., a common practice is to use 35,000 B.t.u. per hour when converting to horsepower.

$$\frac{16{,}234{,}808}{35{,}000} = 464 \text{ boiler horsepower}$$

Two boilers, one 250 hp. and one 300 hp., are suggested for the plant. These units may be operated at 50 percent overload continuously, or 100 percent overload for short periods. This provides for momentary extra steam requirements not included in the above calculations, such as for the hoop washer (49), conveyor pan washer (48), paraffin tank (57), and laboratory equipment.

Ventilating and Air Conditioning

Three types of ventilating and air-conditioning equipment are used in the suggested plant. They are (a) window and roof exhaust fans with ceiling suspended unit heaters for winter heating, (b) recirculating-type air-conditioning units with provision for heating, cooling, and filtering air, and (c) recirculating-type air-conditioning units with provision for heating, cooling, and high efficiency filtration.

WINDOW AND ROOF EXHAUST FANS (130) WITH UNIT HEATERS

This type of ventilation equipment is suggested for the receiving shelter, whey-processing room, refrigeration room, and boiler room. Roof-mounted exhaust fans capable of giving one air change every 4 minutes should be located here, with supplementary roof exhaust fans in the boiler and refrigeration rooms to give an air change every 2 minutes. The supplementary fan in the boiler room would be used on hot days to exhaust radiant heat from the boilers and in the refrigeration room to remove the heat from the electric motor and switchgear given off by the electrical distribution panel. In addition, the supplementary fan in the refrigeration room could be used for rapid ventilation if a serious ammonia leak developed. Both the boiler and refrigeration rooms should have large window areas with insect-proof screens on the outside walls.

The repair shop should be equipped with a wall-type reversible exhaust fan, which can be operated in either direction, according to the personal preference of the workers.

The whey-processing room would have its exhaust fan located over the evaporator to eliminate as much heat as possible given off this unit.

The unit heaters would be used for winter comfort. They utilize steam from the boiler, condensed in a finned coil by an air-circulating fan. The unit heaters are temperature-controlled by room thermostats, with manual start and stop of the fans.

RECIRCULATING AIR-CONDITIONING UNITS FOR HEATING, COOLING, AND PURIFYING AIR

These units are located on the roof, with distribution ductwork on the roof for most areas. Thus, no dust-catching ductwork is located on the ceilings of the cheese-processing areas. Since the office and laboratory areas have suspended ceilings (10-foot ceiling height), distribution ducts are located in the space between the structural ceiling and the false ceiling.

The purposes of these units are to (a) control air purity, thereby improving product quality by reducing the opportunity for any bacteriological contamination or bacteriophage attack; (b) control air temperature for worker comfort; and (c) control humidity with reasonable ranges so as to prevent condensation of moisture on the walls, ceilings, and equipment, and to add to the comfort of the workers.

Air-conditioning units of this type are suggested for the starter room, locker room, cheese-processing room, and reception room.

Air is returned to these units via ducts located near the floor so as to pick up moisture-laden air at the low level. The units are equipped with fresh air inlets and automatic dampers to control the ratio of fresh to circulated air. In winter these dampers automatically adjust themselves to deliver 45° F. air to the heating coil. Thus, when the outside air is 45° or above, all fresh air enters the plant. These dampers are controlled by a thermostat in the air-stream discharge from the dampers.

From the mixing chamber, the air passes through filter elements which remove airborne dust particles. Aside from good housekeeping, control of dust is most important in eliminating poor cheese sets, contaminated cultures, and bacteriophage.

Next, the air passes over a cooling coil refrigerated by 38° F. chilled water, which is circulated by pump through the coils. The air is next brought in contact with a steam-heated coil for winter heating. The heating and cooling coils are controlled by thermostats in the room. For heating, a constant discharge temperature is maintained by a bypass around the heating coil, which is controlled by a damper so as to maintain a set temperature after the heated air and bypassed air are blended together. The cooling coil is controlled by a room thermostat which starts and stops the water circulating pump, plus arranging the fresh air inlet dampers for 10-percent makeup air. Units 124 and 124A have solenoid valves which are controlled by the room thermostats in their respective areas. These units (124 and 124A) are arranged so that the circulating pump (97) is off only when both solenoid valves are closed.

The unit maintains a slight positive pressure in the areas serviced, so that leakage of air is out of rather than into the building. This insures that air entering the building is filtered.

The circulating fan is two-speed. High speed is used whenever the cooling coil is operating or when stepped-up ventilation is desired during periods of cleanup.

The air-conditioning units maintain a 72° F. temperature in both winter and summer except on extremely hot days. On these days a differential of approximately 15° is maintained of inside to outside temperature.

The air-conditioning and purifying unit (123) used for the culture and mother culture room is similar to the units described above except that (a) the cooling capacity is such that a 72° F. temperature can be maintained throughout the hot weather, (b) the air passes through a second set of filters which removes 98 percent of airborne bacteria as well as microscopic dust particles, and (c) the fresh air intake is located 30 feet above the roof to minimize the chance of air contamination from a nearby plant.

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